ENGINEERING

An Illustrated Weekly Journal

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NATIONAL AWARDS FOR IDEAS

THE British Productivity Council have been asked to consider a proposal that cash prizes of £5,000, accompanied by trophies, should be awarded annually for the most outstanding suggestions for cutting production costs. The author of this proposal, Mr. George Ingram, believes that the broad message urging greater industrial productivity, is incapable of inspiring all those in industry who have it in their power to increase productivity.

Mr. Ingram is an industrial member of the Eastern Regional Board for Industry, and it was at a recent meeting of the Board, presided over by Mr. W. W. S. Robertson, of Bedford, that he put forward his plan. He is almost certainly correct in his assumption that the national appeals for greater productivity are only fractionally successful. It is, unfortunately, far easier for political and industrial leaders to identify themselves with the men and women in the factories than for those men and women to be aware of the bond that unites them with their leaders. The channels of communication from the top to the shop floor are fitted with too many non-return valves. The fact is that national appeals, except in the face of a common danger, are of limited value and become less effective the more they are mishandled.

Many men are first conscious of a desire for wealth when, it seems to them, it is too late in life to start acquiring it by hard work. The responsibility of a family, or an awareness of the material benefits that life can bestow, should ideally be a challenge to the individual. But in a world where success in a profession demands study and industry beginning at school, and continuing for many years, the prospects are slender for a man who awakens to reality ten or fifteen years after he left the class-room. It would be easy, but unimaginative, to say that he has only himself to blame. Mr. Ingram believes that many workers in industry dream of a large win on football pools as their only possible escape from a humdrum existence. Before the advent of modern production methods they would have been stimulated by interest in their crafts, but to-day they are denied that reward, and, for the great majority, denied the prospect of earning a substantial capital sum or national recognition from their employment. "This very human urge," Mr. Ingram contends, could be satisfied and channelled into its most useful end by creating national productivity awards.

There may be a possibility of multiplying the opportunities for men who are late in their desire to strive, but it is a slender possibility. Mr. Ingram's idea holds greater promise. It is more hopeful because it is based on a recognition of the prevailing circumstances. He has classified the suggestions which, in his opinion, would qualify for an award. There are four categories: the best labour-saving idea of the year; the best materials-saving idea of the year, preference being given to those ideas which permit home-produced materials to be substituted for imported materials paid for in foreign currency; the best administrative efficiency idea of the year; and the best idea of the year for reducing costs in nationalised industries. The proposed national awards scheme differs fundamentally from the familiar suggestions schemes run by individual firms, though there are a few examples of firms offering fairly substantial sums. By organising a national scheme, the nation's need of higher productivity would be conveyed to the public more forcefully than has so far proved possible. Mr. Ingram suggests that, in addition, leading manufacturers of motor cars, television sets, refrigerators, etc., should be invited to give samples of their products to winners of the awards. Clearly, the aim would be to organise the scheme on a grand scale, sufficient to ensure widespread interest.

The possible success of the idea is closely linked with its practical administration. Who, to ask the first obvious question, would be eligible? Mr. Ingram proposes that the awards should be confined to *bona fide* employees in manufacturing industry and those industries serving manufacturers. Normally, a senior designer, engineer or metallurgist has much greater opportunities for discovering cost-cutting ideas than are open to men on the shop floor. The whole object of the scheme would be almost destroyed if, in the event, it was senior men like these who carried off the awards.

The intention must be to encourage initiative among those who are normally not expected to depart from their routine daily work. Professional men have the chance of promotion and of professional recognition. It might therefore be advisable to restrict eligibility to members of craft and general trade unions, and to have several awards corresponding to the lower supervisory levels as well as non-supervisory workers. If some such formula could be evolved it would have the advantage that the trade unions could participate in organising and administering the scheme. Their co-operation would reinforce the popular appeal of Mr. Ingram's plan. And if the plan is to be adopted it will only succeed by gaining the interest and support of men who are close, in outlook, background and tradition, to those whom it is intended to interest.

Weekly Survey

Cover Picture: *Milling a joint face on a screw-down gear housing for a rolling mill.*

* * *

EQUILIBRIUM IN SHIPBUILDING

We have from time to time in these columns over the past six months drawn attention to the improving prospects of British shipbuilders (Weekly Survey—September 24 and October 29, 1954), although shipowners were slow in placing firm orders. This hesitation in committing their cash reserves was understandable enough, since few if any shipyards could lay a keel until 18 to 24 months after the receipt of an order. The speed at which the spaces in the queue (created by cancellations) were filled by new orders was evidence that, granted reasonable delivery, owners would order first-class modern tonnage, especially motor ships, which had been proved economic even when freights were at their lowest, whereas the older steam vessels hardly paid their way at the highest freight levels. The Engineering Outlook article in this issue includes a detailed analysis of the demand for ships and a discussion of its mainsprings.

The article argues strongly that both technically and economically the outlook for shipbuilding is most promising. The reduction of order books to manageable proportions is not at all a bad thing, since there is every prospect of orders being placed when delivery becomes reasonable. This was clearly demonstrated by the flood of orders that were placed with German shipbuilders, particularly by Norwegian owners, during the past year. Now that the order books of British and foreign builders have been filled to approximately the same level one can expect a good flow of new work, and with adequate supplies of steel plate and other materials and components the British shipbuilding industry should enjoy a long period of prosperity.

* * *

ELECTRICAL ENGINEERS EXHIBITION

If the degree of success of an exhibition can be judged by its rate of growth in succeeding years, then that organised on behalf of the Association of Supervising Electrical Engineers must be counted among the most successful. First held in 1952, in a small way, the exhibition moved to Earls Court the following year, where 103 exhibitors occupied 80,000 square feet. This year, the exhibition to be opened on March 15 by Lord Citrine will occupy 250,000 square feet with over 240 stands. It is essentially a trade show and many of the items would be classed as components, but finished goods are also there, both domestic and industrial. Motors have been chosen to form the main feature, and the range to be displayed is remarkable. The exhibition has been compared to those of 1905 and 1911, both of which were smaller in size although that of 1911 included foreign firms and was the largest held for many years. Brief descriptions of some of the items that will be shown are given in this issue.

* * *

AIR, SEA AND CANAL

The inaugural flight of the Airwork Atlantic freight service on March 1 gives ground for speculation as to the share which air transport may in future secure of the country's import and export trade. Airwork Limited already operate an air freight service between this country and the Continent. In 1954, while the total number of passengers handled at United Kingdom airports increased by 17 per cent. to four million, the tonnage of freight handled rose by nearly a third. The total, at 93,142 short tons, is still very small and a high proportion of it (42,406 short tons) is accounted for by cross-channel freight and vehicle traffic from Lympne and Ferryfield. Next in importance come the London-area aerodromes, which together accounted for 34,368 short tons or 27 per cent. of the total.

By contrast the chairman of the Manchester Ship Canal Company at the ninety-seventh ordinary general meeting stated that the cargoes which passed over the canal and docks in 1954 totalled over 16¼ million tons compared with 12¼ million tons in the previous year. He went on to say that the original promoters of the Canal would look with amazement at the traffic which now passes along it and enters and leaves the Port of Manchester. Should we be equally amazed if we could see the volume of freight which will be carried by air at the corresponding date in the future?

For the present, air freight is likely to be confined to those goods on which the saving in time will more than compensate for the increased cost. Cargo on the first transatlantic flight included woollen goods, jewellery, silverware, pottery, glassware, motor-car and machine-tool parts and a cigarette-making machine weighing 3½ cwt.

* * *

SOUTHERN CROSS

There is such an effect of spaciousness on the Shaw Savill Line's new passenger vessel, the S.S. Southern Cross, that it is difficult to believe she is only 20,000 tons gross. Placing the machinery aft has made it possible to plan the public rooms so that even in bad weather there is ample indoor accommodation for the 1,160 passengers. The lounge deck is particularly roomy, with four public rooms separated only by stairs and hallways.

But the impression of space is not confined to the public rooms. The navigating bridge, galley, boiler room, engine room, and the crew's quarters all appear to have been planned to give the people using them plenty of room to move and work. And yet there has been no cramping of the passenger accommodation. Cabins are arranged for from one to six passengers, most being four and six-berth cabins; a large number are centre-line cabins, but they are well ventilated and air-conditioned.

On a short cruise from Liverpool to Southampton last week-end the steadiness of the Southern Cross, in spite of fresh weather, was remarkable, even when the stabilisers were not in use. She is the first vessel to have been planned for passengers only, and she will therefore be subject to none of the delays that loading of cargo often causes. Earning power is decreased by the lack of cargo space, but increased by the ability to make four instead of three round-the-world trips in a year. The Southern Cross is making more short " shake-down " cruises, and departs on her maiden voyage on March 29. We shall be publishing a description of the ship in a forthcoming issue.

* * *

THE POWER GAS CORPORATION

A company which should have an important contribution to make to the recently announced plans for the expansion of the British iron and steel industry is the Power Gas Corporation, through its Subsidiary, Ashmore, Benson, Pease & Company, one of whose main activities is the construction of blast furnaces. The chairman's statement accompanying the annual report for the year ending September 30, 1954, points out that since the war the company have completed or have under construction twenty-three blast furnaces to produce more than 16,000 tons of iron per day, equal to almost half the total iron being produced in the United Kingdom.

The company's work in this field covers also blast-furnace auxiliaries, rolling stock and pig-casting machines. During the past year two blast furnaces were completed for the Appleby-Frodingham Steel Company, Limited, with a combined output of 600,000 tons of pig iron a year from low-grade ores. Among recent orders received was one obtained against strong international competition for the construction of two blast furnaces for the Burnpur works of the Indian Iron and Steel Company. Other products of the company concerned with iron and steel production include a range of structural steelwork and, in particular, ore reclaiming and stocking bridges, and sintering plants. The largest ore bridge in the United Kingdom, having a span of 300 ft. and embodying 800 tons of steel, was built by the company for the Consett Iron Company.

Products of the company also include water-gas plant and other equipment for the gas industry, chemical plant and, through their subsidiary, Rose, Downs and Thompson, Limited, expeller presses and solvent-extraction plants for vegetable oil mills, fish-meal plants and whale factory ships. The water-gas plants were completed during the year 1953-54, including three additional carburetted water-gas units at the Beckton works of the North Thames Gas Board and a carburetted water-gas plant installed by Ashmore, Benson, Pease and Company, Africa (Pty.), Limited, (a subsidiary of the Power Gas Corporation) for the town council of Springs on the Witwatersrand. In co-operation with the U.S. Girdler Corporation the company completed a de-sulphurising plant at the Grangemouth refinery of the British Petroleum Company, Limited, and also a deodorising plant in a vegetable oil mill.

The chairman reports that total orders received during the year showed a decline for the second year in succession, to £5·5 million. Nevertheless, the company has spent £643,000 on capital development, mainly on extensions to the constructional shop and on a new heavy machine shop at the South Works at Stockton, as a result of which the company expect to be able to offer quicker delivery and lower prices. These improved facilities may well be needed during the current year since orders received during the first quarter are stated to have amounted to £4·25 million.

* * *

POWER FOR CENTRAL AFRICA

In the Zambezi and its tributaries the Government of the Central African Federation has at its disposal a large potential of hydro-electric power. In particular two great schemes—the Kariba and the Kafue—have been canvassed for many years. But now the demand for power, especially for the Copperbelt, has meant that the decision has had to be taken as to which of the two schemes should be promoted first. The choice of the Government has been for the scheme located on the Zambezi itself at a point where the river passes through the Kariba Gorge. A dam only 400 ft. high built in the Gorge will cause a lake 150 miles long to be formed, giving the project an estimated regulated output capacity of 1,000 MW at 70 per cent. load factor. Some details and contrasting merits of the Kariba and Kafue schemes were published in ENGINEERING last year (vol. 177, page 644).

The advantages favouring the chosen Kariba scheme are its greater potentiality, which is known with a fair degree of accuracy, and that it can be built in stages, the generating equipment being installed as required after the dam is built. Its disadvantages as compared with the Kafue are its greater distance from the Copperbelt, where the power is required immediately, and it cannot produce some part of its output as quickly as would be possible at Kafue. Nevertheless power from the Kariba will ultimately be more generally available to industry than power from Kafue can be, and from 1961, when it can be brought into commission, it should stimulate new industries, particularly in Southern Rhodesia, giving much needed employment for the African other than on the land. It would seem wise not to sacrifice the Kariba for the short-term advantages of the Kafue project.

Announcing the decision in the Federation

Parliament, Sir Godfrey Huggins said the project, with six generating sets installed, would cost £54 million, of which the Federation would contribute £8 million. The International Bank for Reconstruction and Development had been approached, inviting an investigation of the project by an economic mission, to be followed later by a technical appraisal. The Government's final decision to commence work depended only on favourable reports of the Bank's missions supported by the promise of the still-required financial assistance. The United Kingdom Government, continued Sir Godfrey, regarded the completion of the project as of major importance to them and were giving all the help they could.

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DEVELOPING UGANDA

In the last few weeks the final stages in the construction of the 132-kV transmission lines carrying power from the new Owen Falls hydro-electric scheme to Kampala and Tororo have been reached. These 114 miles of line are the first stage in the development of a grid transmission system across Uganda. At the moment, lines are operating at 33 kV but they are expected to go on full voltage later this year.

By a coincidence, the five-year development plan for the colony has also been published recently. Uganda expects to spend at least £30 million on capital development in the years 1955-1960. Much of this is to come from the colony's revenue, which has been particularly buoyant of recent years owing to the good prices obtained for cotton and coffee, but some of the money is to come from internal loans and grants from funds, among which will be included the United Kingdom Colonial Development and Welfare Fund.

One of the points arising out of the capital development programme is that no matter how important it may be to secure cheap power for the development of a colony, this power cannot be translated into industries—or even into industrial opportunity—overnight. Industry needs good communications as well as cheap power and 20 per cent. of Uganda's five-year scheme is going on roads and civil aviation. The largest amount (23 per cent.) will be on urban services including housing and water development, and what to the outsider is the surprisingly high figure of 25 per cent. is to go on general administration, internal security, law and order. It is clear that only gradually can the big industrial potential arising out of the Owen Falls hydro-electric scheme be realised (though the increasing electricity demand has more than kept pace with the provision of new generating capacity). In the interim period, however, there are obviously opportunities for civil and constructional engineering companies. Urban water supplies and sewerage schemes alone account for £1½ million of the proposed expenditure.

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DOMESTIC APPLIANCES

Sir Charles Colston, former chairman and managing director of Hoover Limited and, until recently, vice-chairman of the Independent Television Authority, announced last week his decision to return to the production of domestic appliances with a new company, Charles Colston Limited. In his statement, Sir Charles emphasised that he considers the housewife is well served by the electric cleaner and electric washing machine " with whose development I have been closely associated in the past." But in his opinion, there is " a considerable field where insufficient progress has been made in the development of labour-saving household appliances which, provided they can be produced at a moderate price, can be an immense boon to the housewife." Sir Charles does not say to what appliances his statement refers, but that he is in close touch with inventors in this country and in the United States. Apart from completely revolutionary products yet unthought of, it is likely that he has in mind electric rotating clothes dryers, ironers, dish washers and food mixers. There have been increasing sales of these appliances in the United States, but so far no relatively cheap version has been successfully marketed.

Charles Colston Limited have acquired a factory in County Durham with an area of 35,000 square feet where 250 operatives will be employed. Within a year, the company hope to have four or five further factories employing over 1,000. There is little doubt that if Charles Colston Limited could make available in this country and in the Commonwealth the appliances that would enable the housewife to wash up, dry and iron clothes, make cakes with a fraction of the effort now necessary, and do that at a price that could be paid off by most households within one to two years, he would find his projected small factories hopelessly inadequate within a few months. There is an opportunity in this field and it is as large as the mass market to which the appeal is being made.

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AUTOMATION

The Institution of Production Engineers have chosen for their summer conference a subject that is well to the fore at the present time—namely, the automatic factory. At the conference, which is to be held at Margate from June 16 to 19, seventeen papers will be presented by authorities in different sections of the work, including one from France and one from Switzerland. As well as the purely mechanical side, there are to be papers on the repercussions in education, and on the trade union reactions. The conference secretary is Mr. S. Castleton, 10 Chesterfield-street, London, W.1.

An introduction to the conference was made at a gathering held on March 2, when Major-General K. C. Appleyard and Sir Walter Puckey, President of the Institution, spoke on the points that were involved. General Appleyard said that the development of automation was merely the logical growth from the first use of machinery, developing as new tools became available. It could roughly be divided into two sections: reducing brain work by calculating machines of varying complexity, and reducing hand work by the use of power tools. Both sections would be included in the conference.

Sir Walter Puckey's statement dealt more with the general industrial view and how the capital expenditure now being contemplated would almost inevitably require more mechanisation and more automation. In particular, he added that with the present full employment, and the proposed increases in production, there could be no possibility of men being put out of work by the new machines. Anyone displaced in one section could immediately be absorbed in another, and, far from degradation, the new factories would offer far greater opportunities for workpeople than had been available in the past. The automatic factory would also be a safer place. These aspects, too, would be covered by papers at the conference.

Also in connection with automation, the February bulletin of the Production Engineering Research Association (whose headquarters are at Melton Mowbray, Leicestershire) announces the formation of a technical committee to consider problems involved in the use of automatic systems. One particular facet that will be dealt with will be the development of systems which have sufficient flexibility for use in small concerns, or when only a small number of items is required.

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FIRST BRITISH 200-MW TURBO-ALTERNATOR

The announcement by the British Electricity Authority that it has ordered a 200-MW turbo-alternator with its associated " unit " boiler, for probable installation in the High Marnham station on the River Trent, is a notable event. Both set and boiler will be larger than any that have hitherto been built in this country; and the steam conditions, although not exceptional, will be unusual. The decision, which is not without boldness, is a tribute to the success of the work that has been carried out in recent years in the field of boiler design and on materials capable of withstanding high temperatures and pressures. It is also an indication that the Authority is not unduly perturbed at the suggestion that the nuclear reactor will rapidly replace the boiler as a steam generator.

An incidental, although not unimportant, result of this development is the saving in space which it will allow. As will be seen from the figures reproduced on page 295 of this issue, it has been possible, owing to advances in design, to reduce the enclosed space in power stations from 49·4 cub. ft. per kilowatt installed in 1948 to 30·5 cub. ft. in 1952 and the latter figure will have fallen to 18·9 cub. ft. by 1957, a total reduction of 62 per cent. By the time High Marnham is in operation there may well have been an even further decrease. This should have an appreciable effect on the capital cost of the plant and enable an interesting comparison to be made between the relative economies of existing and more spectacular methods of raising steam.

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NAVAL OFFICERS

The entry, training and promotion of officers in the Navy has always been a matter of constant concern with the Admiralty and again and again regulations have had to be revised to meet the changes in Fleets and Establishments brought about by modern developments. One such notable revision was made about half a century ago when the famous Selborne-Fisher scheme was introduced with the object of ensuring an adequate supply of properly trained officers for all branches, especially for the then-called " military " branch and the engineering branch, the officers of which were curiously known as " non-combatants." From the Selborne-Fisher scheme, which led to the closing down of the old training ship H.M.S. Britannia and the opening of Osborne and Dartmouth colleges, dates the modern history of naval personnel. But change continues to succeed change and some of the present problems of the Admiralty were referred to by Mr. J. P. L. Thomas, First Lord of the Admiralty, in his speech to the House of Commons on March 3 when he presented the Navy Estimates.

Owing to the greatly increased staffs necessary for training, research, development and administration, it is no longer possible to give all executive commanders and captains the same opportunities for commands at sea and it has therefore been decided to separate these officers into two lists, to be known as the " Post List " and the " General List " and only officers on the former will be eligible for sea-going command. The size and complexity of the problem will be realised when it is stated that in February, 1955, there were no fewer than 318 Captains and 645 Commanders on the Active List. While this change affects the executive branch, another affects the officers of the engineering, electrical and supply and secretarial branches, against whose names the suffixes (E), (L) and (S) will no longer be placed. At the same time, the distinctive coloured stripe between the gold lace on the sleeves will disappear.

The history of these stripes goes back to 1863 when medical officers were given scarlet stripes, which they are to retain, and engineers the well-known purple stripe. Further, to improve the status of non-executive officers, rules governing the award of marks of respect to senior officers are to be amended so that " these officers receive marks of respect according to their ranks and appointments comparable to those given to executive officers." This is a salutory reform and it is one which is to be applied also to officers of the Royal Naval Reserve and the Royal Naval Volunteer Reserve.

CANBERRA FLIGHT

Oxygen Masks in a Pressurised Cabin

In view of the recent correspondence in *The Times* on the possibility of reverting to unpressurised air-liners—a suggestion put forward by Professor J. B. S. Haldane after the publication of the Comet inquiry findings—it may be of interest to record some of the impressions of a member of ENGINEERING's editorial staff who recently had the opportunity of flying in an operational Canberra aircraft piloted by Flight Lieutenant Hillier, No. 207 Squadron, R.A.F. Station, Marham, Bomber Command.

The Canberra is not, of course, an unpressurised aircraft and during the flight the cabin "altitude" never rose above 20,000 ft. It is, however, pressurised to a much lower degree than is customary in air-liners, mainly because the hazard of explosive decompression as a result of damage in combat, and oxygen masks are worn throughout the flight. Moreover, all aircrew and passengers in R.A.F. Canberra aircraft are required to undergo a decompression test—in the case of aircrew this is repeated every four years or so. The purpose of this is to detect any physical weaknesses that might adversely affect the subject at altitude—an exceptional tendency to "bends," inability to equalise pressure on the eardrums, etc.

At Marham, the test is carried out in a mobile decompression chamber, comprising a horizontal steel cylinder furnished with comfortable seats and standard aircraft-type oxygen supply points for testing six personnel simultaneously. The test observer controlling the exhauster pump remains outside the chamber and views the subjects under test through an observation window.

The full test for aircrew comprises a quick "climb" in about 10 minutes to 25,000 ft.; an hour maintained at 25,000 ft.; a further climb to 37,000 ft. and again an hour at this altitude, followed by a rapid descent (3,000–4,000 ft. per minute) to ground level. The higher altitude requirement is considered a stringent one. Because the time available was limited, ENGINEERING ascended only to 25,000 ft. Even so it was a noticeably uncomfortable experience as the cabin "ascended" above 20,000 ft. Wearing the unfamiliar oxygen mask, a conscious and continuous effort was required to keep the ears cleared—on the climb as well as during descent—even for one aware of the need to equalise pressure on the eardrums. Admittedly, the rates of pressure change in the decompression chamber were much higher than would be encountered in a civil air-liner.

Since ENGINEERING's representative had not flown in a bomber aircraft since the end of the second World War, the flight in the Canberra was full of interest. The remarkable absence of noise and vibration; the attainment of speeds at which a slight juddering due to compressibility effects was just beginning to be felt, and the subsequent smooth recovery using dive brakes; the beautiful handling qualities and steadiness of the aircraft in "hands-off" trimmed flight; its ability to climb comfortably on one engine—the demonstration of all these factors was calculated to minimise any physical discomfort arising from the use of the oxygen mask. The fact remains that it was found to be uncomfortably hot and irritating to the skin, and for many air-liner passengers without the distraction of an absorbing technical interest in the flight, the necessity for wearing an oxygen mask for several hours would probably be not only tedious but distressing.

Quite apart from technical and economic arguments (which we believe in any case to be decisive), there is unlikely to be much serious support for the plea for unpressurised air-liners with oxygen supplies to the passengers, particularly since this would imply the retention of the obsolescent piston engine with its inevitable vibrations.

A NEW SHIP TANK FOR THE N.P.L.

The National Physical Laboratory is to be provided with a new Ship Hydrodynamics Laboratory. Sir William Stanier, F.R.S., chairman of the Froude Ship Research Sub-Committee, cut the first sod this week (on March 7) on the site at Faggs-road, Feltham, Middlesex. The main contractors, Sir Robert McAlpine and Sons, Limited, are now at work and the laboratory is expected to be complete by the summer of 1958.

Attention is turning more and more to the behaviour of ships in a seaway and to means of making ships more seakindly. These and other problems will be studied in the new laboratory. The facilities will include a ship-model tank, 1,300 ft. long on the main waterway, 48 ft. broad and 25 ft. deep, spanned by a carriage having a top speed in excess of 50 ft. per second, and fine control down to 1 ft. per second. (The existing Yarrow tank is 550 ft. long, 30 ft. broad by 12 ft. deep, with a top carriage speed of 20 ft. per second.) A feature of the carriage will be the clear platform provided all round and the portable centre beam carrying all the dynamometer gear. The tank will be provided with a wavemaker to simulate a wide range of head and following sea conditions. Ground is available to extend the tank to 2,000 ft.

In the same building there will be a steering and storage pond 140 ft. by 100 ft. by 8 ft. deep, in which steering and manœuvring experiments will be carried out using radio-controlled models about 8 ft. long. There will also be a laboratory for the study of vibration problems on ship hulls. Workshops will be provided to make model hulls in wax or wood up to 35 ft. in length, to manufacture model propellers up to 24 in. in diameter, and to make dynamometer apparatus.

A separate building will house a water tunnel having a 44-in. diameter working section and a top speed of at least 50 ft. per second. This will be pressurised and will be able to test propellers up to 24 in. in diameter. It will be provided with an air resorber circuit which will enable the dissolved air content of the tunnel water to be controlled. In the same building provision is being made for the installation of a water flume of a new design having a test section about 8 ft. broad by 4 ft. deep, in which flow and pressure measurements will be carried out.

The main tank foundations will be laid on a gravel bed about 7 ft. below ground level, and the whole will be enclosed in a light steel and aluminium-framed structure, clad externally in asbestos-cement sheeting. The internal lining will be insulating panels to minimise heat transfer and resist the effect of excessive humidity.

An accurate and stable base for the carriage track must be provided—a railroad about a third of a mile in length, located true to within a few thousandths of an inch after allowing for the curvature of the earth's surface. The track will consist of special-section rolled steel rail of approximately 207 lb. per yard weight, machined on base and head, and laid in chairs designed to give extreme accuracy. The joints will be fusion-welded and machined *in situ*.

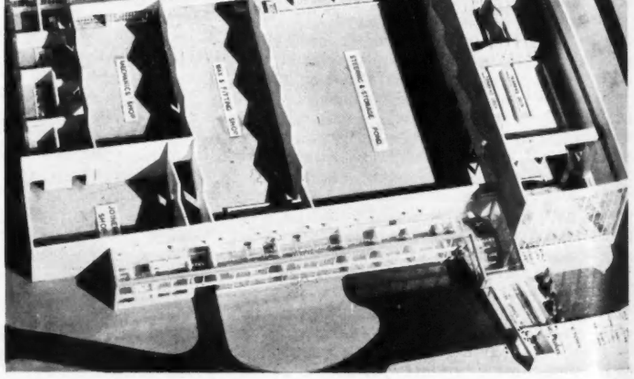
The carriage, the design of which has still to be finalised, is intended to tow models of up to 10 tons. It will be of tubular construction and has been designed as an open rectangular frame, having a clear area within to permit alternative positions of the dynamometer boom—a longitudinal member from which the model is supported via the dynamometer used for measuring the forces on the model. Due regard has been paid to the problems of resonant vibration, which can adversely affect the dynamometer recordings.

The carriage will be driven by four twin-wheeled bogies located at the corners, each powered by a 300-h.p. motor. These will be connected in series-parallel and supplied from a Ward Leonard set. The connections between the carriage and the Ward Leonard generator will consist of a set of rigid conductor rails running down the outside of the tank walls, with collector arms on the carriage itself. The design envisages a system of automatic speed control, derived from previous experience of this problem on the existing ship tank carriages of Teddington. Regenerative braking will be employed, in addition to a friction brake operating on the sides of a brake rail. A form of arrester gear is being developed for emergency stopping at the far end of the tank.

The lighting system will consist of cold-cathode fluorescent tubes mounted so as to form virtually a continuous run down each side wall of the tank building, below the truss level, and arranged so that even illumination is given of the side gangways and the roof but no light is thrown on the water.

The heating and ventilating system will consist of background heating using low-pressure hot-water convectors thermostatically controlled, together with a plenum system which will introduce warmed air from a duct running along the roof apex and discharging through low-level grilles at walk-way level. The degree of heating of the incoming air and the amount of re-circulation will be automatically controlled by the humidity conditions in the building.

The site will be supplied with power at 6·6 kV from the system of the Southern Electricity Board. An initial demand of approximately 3,000 kW is anticipated. The building contract amounts to approximately £750,000 in value and the estimated total value of all works services, according to the Ministry of Works, is £2,000,000.



A model of the new ship hydrodynamics laboratory which is being built at Feltham for the National Physical Laboratory. Only the near end of the 1,300-ft. long tank is visible at the top right corner of the picture.

Letters to the Editor

INDUSTRY AND THE LOCAL TECHNICAL COLLEGE

Provision of Library Services

SIR, The statements made by the speakers at the Conference on "Co-operation in Engineering Research between Educational Institutions and Industry," held at the Institution of Mechanical Engineers, and reported in your issue of February 4, point to an apparent failure in the policy of research associations, Aslib, the Technical Information and Documents Unit of D.I.S.R. and other Government information services to disseminate technical data. On the other hand, at the Aslib Conference before Christmas, librarians and information officers lamented at the few scientists and technologists who could use information services profitably.

In your issue of February 25, Mr. Leslie Wilson illustrates the little consideration industry as a whole has given to this problem, which is not surprising when so little attention has been given in the past to the training of students in the use of books at school. Even now the niggardliness of many education authorities in the provision of school libraries is the subject of much comment. It has, however, been most marked in technical colleges. Whereas a library in a university plays a major role in the training of a scientist, the technician and technologist, the backbone of our industrial labour force, have rarely experienced similar facilities. Indeed, the vast majority have had no training at their technical college in how to seek, collate and apply the theories of others for themselves.

Although many excellent reports have been issued on the formation of libraries in these colleges, few authorities have implemented them and there has been no strong lead to encourage their establishment by Government departments and associations specifically interested in this matter. Even Mr. Rates in his letter (ENGINEERING, February 25) shows little sorrow that the finances of so many colleges are pitifully small and yet ignores the fact that if these students are not trained in the use of books they will not be able to use the facilities he as a borough librarian hopes to provide.

On the credit side it is a pity that no one has alluded to the contribution already being made by those colleges where libraries are firmly established and staffed by experienced librarians. Many of these colleges are not only spending more on technical literature than most public libraries but have special collections available to industry unequalled by the public libraries in their area or elsewhere. A few examples of good libraries may not be out of place: Manchester College of Technology, 40,000 volumes and 450 periodicals; Glasgow, 22,000 volumes and 360 periodicals; Northern Polytechnic, 14,000 volumes and 215 periodicals; Leicester, 15,000 volumes and 394 periodicals. Even in those libraries only recently established in London there are many unique collections, for example, Westminster Technical College, soil mechanics, and the London School of Printing and the Brixton School of Building. These are all playing a very effective part in the dissemination of information to industry. It should be borne in mind that apart from direct loans and telephone inquiries, the part-time staff of these establishments are drawn from local industry and they frequently use the facilities both for lectures and for their industrial problems. Part-time students are in a similar position.

Public library co-operation is vital and necessary but as a rule the facilities they provide can at the best be only those of a clearing house for they do not employ the specialist, and yet frequently the individual seeking technical information requires the assistance of the consultant. A technical college library is in the happy position of having such staff on the spot. The danger, and it is a very real one, is in the provision of technical library facilities in the smaller provincial towns where the funds for public library and college come from the same pocket. Here it is not unusual for the public library resources to be built up to the exclusion of the technical college.

The technical college needs an efficient library staffed by skilled librarians and co-operation with local industry is essential for the well-being of the college. I submit that a library information service centred in a technical college is a most valuable method for strengthening those ties with industry. Many firms are willing to give equipment to a college: those firms who are unable to afford libraries of their own may well consider the idea of assisting in the provision of a library service in their local college, while the Government information services could well give a practical lead.

Yours faithfully,
GORDON H. WRIGHT.

Greenway Court,
Hollingbourne,
Kent.
March 2, 1955.

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LOW-FRICTION FLUID SEALS

The Retort Courteous

SIR, We have read with much interest Mr. B. Cooke's letter (ENGINEERING, March 4), in connection with the article on Low-Friction Seals, which appeared in a recent issue of your journal (February 4), and must entirely agree with him that the value of the article would have been greatly enhanced had it been possible to quote definite, or even approximate, friction figures.

Knowing, however, the extensive research work your correspondent has himself carried out on the subject, we are sure he will be fully aware that it is virtually meaningless to quote friction values in respect of any particular type of packing or seal without reference to all the conditions and circumstances under which they are to be used, and which, with practically every type of packing and seal, are many and varied.

Naturally, friction values will alter tremendously according to the nature of the application and the operating conditions.

In regard to Mr. Cooke's statement that he has had difficulty in obtaining information regarding the friction of seals for reciprocating applications, we assume he is referring in this instance to specific cases where full details of the application and working conditions are known. In these circumstances it is admitted that it is, of course, possible under carefully controlled laboratory conditions to calculate approximate friction values for any particular packing or seal of a given type and size, under a given set of conditions, for a given application.

We maintain, however, that results so obtained are of little value to designers, as the closely controlled conditions under which the laboratory test is carried out are never reproduced in actual practice. Dimensional tolerances of the metal parts and of the packing itself, and the degree of mechanical compression applied to the packing, can alone have a very appreciable effect on friction values, to say nothing of numerous other variables, which can be closely controlled in a laboratory but not in the average industrial application. Because of this, we know from bitter experience that, owing to a number of unknown or uncertain factors, mostly involving the human element and entirely beyond the control of the packing manufacturer, results experienced in actual service seldom, if ever, bear any relationship to those obtained under laboratory test, and the discrepancy is often a very wide one indeed.

It should not be assumed that lack of available data on the subject of friction of packing and seals is indicative of lassitude on the part of manufacturers, or of their failure to appreciate its importance. Their interest is proved by the fact that many of them, including ourselves, are engaged unceasingly in research work into this most complex problem, and by their efforts to introduce packings designed to give the minimum of frictional resistance compatible with other essential features, such as sealing efficiency and long life, as in the case of our own Lion "Twinset."

It is, in fact, because of their realisation of the importance and complexity of the problem that they decline to give information, which far from being of assistance to designers, they know must in most cases be of doubtful value and in some definitely misleading and even dangerous.

Yours faithfully,
T. F. WATSON,
Director.

James Walker and Company, Limited,
Woking, Surrey.
March 4, 1955.

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WEIGHING THE OUTPUT OF A COLLIERY

Possible Extensions to the Scheme

SIR, The article with the above title which appeared in your issue of February 4 (page 156), describing the machine installed at Whitwick Colliery, Leicestershire, was interesting as another example of mechanisation in colliery practice. One feels that it should be possible, by modification of this automatic weighing and totalising machine, to obtain further valuable information. Since individual tub weights are indicated on the dial, provision could be made for these individual weights to be recorded. In addition, symbols could be printed against each weight to record, if necessary, a different seam or district.

Generally, the refuse content of a tub of coal can be roughly judged by its weight. By use of this method the colliery officials could be provided with a guide as to the quality of the run-of-mine coal at any time or from any district other than where central loading is practised. The recorded weights would also act as a check on the totaliser mechanism.

Yours faithfully,
J. H. GOLD.

42 Holywell-avenue,
Whitley Bay,
Northumberland.
March 1, 1955.

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THICK-WALLED CYLINDERS UNDER INTERNAL PRESSURE

Tensile Stresses at Failure

SIR, We should like the opportunity to reply to the comments made by Dr. van Iterson (ENGINEERING, March 4) on our article on the ultimate strength of thick-walled cylinders—comments which we both greatly welcomed.

Dr. van Iterson suggests that his equation gives lower results than the measured values because he has not allowed for the increase in diameter. This increase in diameter, however, causes an appreciable weakening effect as the value of K decreases as the cylinder swells. For instance, cylinder 13 initially had a K of 3·717, but at ultimate pressure this had reduced to 2·81.

The equation in question seems to have been derived by substituting R, the ultimate tensile strength of the material, for S_0 in the equation for the pressure p at which the entire cylinder just becomes plastic, that is, the equation $p = S_0 \log_e K$ where S_0 is the tensile yield stress and K the initial ratio of outer to inner diameters. We cannot see any theoretical justification for this substitution and are of the opinion that even the approximate agreement between the equation and the experimental results is entirely fortuitous. Again we would emphasise that the Manning solution to this problem seems to be the only one which really allows for the change in K at strain reached at the ultimate pressure.

Yours faithfully,
B. CROSSLAND and J. A. BONES.

University Engineering Laboratories,
Bristol, 8.
February 25, 1955.

PERSONAL

AIR MARSHAL SIR VICTOR GODDARD, K.C.B., C.B.E., has joined Elliott Brothers (London) Ltd., Century Works, Lewisham, S.E.13, as an assistant (air) to the managing director.

MR. W. R. FLETCHER, B.Sc. (Eng.), A.M.I.E.E., has been appointed engineer-in-charge at the Brookmans Park transmitting station, of the British Broadcasting Corporation in succession to MR. D. HAMILTON-SCHASCHKE, who has become resident engineer, British Far Eastern Broadcasting Service, Singapore.

MR. S. F. MITMAN, C.B.E., has been appointed deputy chairman and managing director of Borg-Warner Ltd.

MR. A. D. MCLEAN, B.Sc., joined the board of the Nobel Division of Imperial Chemical Industries Ltd. on March 1, as home sales director.

BRIGADIER F. W. S. GORDON-HALL, C.B.E., director of inspection of fighting vehicles, Ministry of Supply, has been given the temporary rank of major-general and appointed director-general of fighting vehicles, Ministry of Supply, with effect from June, 1955. MAJOR-GENERAL H. R. B. FOOTE, V.C., C.B., D.S.O., director-general of fighting vehicles, Ministry of Supply, is to be director, Royal Armoured Corps, War Office, with effect from August, 1955.

MR. D. W. BOTTLE, B.Sc., A.C.G.I., A.M.I.Mech.E., A.F.R.Ae.S., has been appointed chief aerodynamicist of Short Bros. & Harland Ltd., Belfast, Northern Ireland.

DR. R. L. HEARN has been appointed chairman of the Hydro-Electric Power Commission of Ontario, in succession to MR. R. H. SAUNDERS, who was killed in an aircraft accident in January. Dr. Hearn was formerly the Commission's general manager and chief engineer and has also been in charge of their atomic-power research programme.

Consequent upon MR. F. J. E. TEARLE's appointment to the A.E.I. Overseas Group, MR. F. R. MASON has been appointed general manager, Metropolitan-Vickers Electrical Export Co. Ltd., Trafford Park, Manchester, 17. MR. G. H. JOLLEY, M.I.Mech.E., has been appointed principal representative of the Export Company at Trafford Park in succession to Mr. Mason.

MR. E. ALEXANDER, A.M.I.E.E., A.M.I.P.E., has been appointed manager of the Willesden Works of the British Thomson-Houston Co., Ltd., Rugby, in succession to MR. H. E. COX, M.I.E.E., who, as reported on page 135, *ante*, has been appointed manager of the firm's Rugby Works. MR. C. F. HUMPHREYS, A.I.E.E., formerly engineering superintendent, has been appointed manager, switchgear-engineering department. DR. J. R. MORTLOCK, B.Sc. (Eng.), M.I.E.E., has been appointed manager, power-system engineering department. All the above appointments date from March 1.

SQUADRON LEADER L. M. WHITTINGTON, A.F.C., until recently an assistant experimental pilot with the English Electric Co. Ltd., has joined Folland Aircraft Ltd., Hamble, Southampton, as assistant to SQUADRON LEADER E. A. TENNANT, D.F.C., the company's chief test pilot.

The General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.2, announce that MR. R. N. MILLAR, lately chief mechanical engineer to the British General Electric Co. (Pty.) Ltd., Australia, has been appointed to take charge of the firm's newly-formed industrial atomic-energy section, at the company's Erith works, Kent.

MR. J. E. HARVEY, general manager of Marine and Industrial Lubricants Ltd., has been appointed to the board of the company.

The Society of Motor Manufacturers and Traders, 148, Piccadilly, London, W.1, announce that following the appointment of MR. S. E. CLARK, O.B.E., as chief executive officer, MR. D. E. GOUGH, formerly overseas secretary, now becomes manager, British manufacturers' section and overseas secretary. MR. W. T. WILLIAMS, formerly head of the legal department, is appointed secretary.

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COMMERCIAL

HENRY MEADOWS LTD., Fallings Park, Wolverhampton, have formed a gearbox division to handle the production and sales of marine, internal-combustion engine and industrial gearboxes.

MONSANTO CHEMICALS LTD., 8, Waterloo-place, London, S.W.1, have announced that steps are being taken to form a new wholly-owned subsidiary company, MONSANTO PHOSPHATES LTD., for the production of sodium phosphates and other phosphorus compounds. The first plant will be at Newport, Monmouthshire; it will produce sodium polyphosphate used mainly for detergent applications. Monsanto Phosphates Ltd. will administer the present interest of Monsanto Chemicals Ltd. in the TORORO EXPLORATION CO. LTD. in connection with the industrial processing of phosphate deposits in Uganda. The general manager of the new company is MR. J. M. KERSHAW and the directors are: DR. J. W. BARRETT, MR. D. R. MACKIE, MR. H. S. PARRY, MR. N. F. PATTERSON, MR. D. C. M. SALT, and MR. P. A. SINGLETON.

A new agreement has been signed by the CHISHOLM RYDER CO. INC. of the United States, and FREDERICK C. KANE, LTD., Park Royal, London, N.W.10, to manufacture, in this country, a wider range of the former company's food-processing machinery.

E. & L. B. PINKNEY (MARINE) LTD., Zetland-road, Middlesbrough, have taken over the production and marketing, at home and abroad, of the Feltham range of marine engines and reversing gears formerly produced by BRUCE & HOLROYD LTD., Feltham, Middlesex.

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Obituary

MR. W. J. H. WOOD
Electricity Supply

Electricity supply engineers will learn with regret of the death of Mr. W. J. H. Wood, which occurred at Sevenoaks on Wednesday, March 2, at the age of 76. He had been connected for many years with electrical power undertakings and had been responsible for the construction of a number of generating stations, including those at Barking and Littlebrook.

William John Hanvey Wood was born in Antwerp on August 10, 1878 and was educated at the Deutsche Oberrealschule in that city. After serving a three-year apprenticeship with the Cie Le Phoenix and the Cie Hydro-Electrique in Antwerp, he attended a two-year course at the Crystal Palace School of Engineering, gaining the first place in both mechanical and electrical engineering.

In 1899 he obtained an appointment as switchboard attendant in the Edinburgh Corporation Electricity Department and a year later became junior engineer. In 1902 he joined the Electricity Department of the Bolton Corporation and served with them for the next 25 years, being successively shift engineer, station superintendent and borough electrical engineer. During this period he was responsible for the design and erection of the Back o' th' Bank power station, which was opened in 1914. He also acted for a time as consulting engineer to the Rochdale Corporation.

In 1927 he was appointed engineer-in-chief and joint general manager of the County of London Electric Supply Company, a concern which then supplied electricity over a very large area in London and its environs. Mr. Wood was responsible for the engineering side of this undertaking and carried out extensions to the well-known station on the Barking site as well as initiating the construction of the A and B stations at Littlebrook, in the second of which the first hydrogen-cooled alternators in this country were installed. He was also a director of the Kent Electric Power Company. He retired on the nationalisation of the electricity supply industry in 1948, but became a part-time member of the London Electricity Board.

Mr. Wood was elected an Associate Member of the Institution of Mechanical Engineers in 1904 and transferred to the class of members in 1918. His connection with the Institution of Electrical Engineers began in 1912 when he became an Associate Member. He was transferred to the class of member in 1918, served on the Council from 1934 to 1937 and as vice-president in 1944-45. He was also the holder of a Swan premium.

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MR. D. MACADIE, M.B.E.
Instrument Inventor

We regret to record the death of Mr. D. Macadie, which occurred on February 13, at the age of eighty-four. He was well known as the inventor of the AvoMeter, a multi-range ammeter, voltmeter and ohmmeter and of a number of other testing instruments.

Donald Macadie was born in Caithness, and entered the employment of the Edison-Bell Phonograph Company in London at an early age. He was subsequently engaged with the National Telephone Company in Liverpool and Nottingham and when that concern was taken over by the Post Office was placed in charge of the Department's factories in Birmingham and London. While holding these positions he exercised his great abilities as an inventor and designer in the production of many types of apparatus including a machine for binding telephone cords and a key sender for private branch exchanges, which reduced the time of transmitting seven-digit outward calls from 10 sec. to 2½ sec. He was also largely responsible for designing a machine for sorting cancelled postal orders and for devising a multi-head coil winder, by means of which 12 coils could be dealt with simultaneously.

In 1923 he was instrumental in establishing the Automatic Coil Winder and Electrical Equipment Company, Limited, to manufacture the AvoMeter and other instruments, and since his retirement from the Post Office in 1933 he had devoted a good deal of time to the business of this concern. He was appointed a Member of the Order of the British Empire in 1932.

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We regret also to record the deaths of:

MAJOR MICHAEL STEPHEN THOMPSON, M.I.C.E. of High Halden, Kent, on February 23, at the age of 73. He served in the Royal Engineers in the war of 1914–18, and afterwards became general manager, Santander-Mediterraneo Railway, Spain. During the past few years Major Thompson had served on the technical staff of the Directorate of Opencast Coal Production, first in Newcastle-upon-Tyne, and subsequently at Cardiff.

MR. CEDRIC PHILLIPS LOCKTON, which occurred on February 20 at the age of 52. He joined the Chloride Electrical Storage Co. Ltd. (now Chloride Batteries Ltd.) as assistant chief engineer in 1924 and was appointed chief engineer in 1949. He was a specialist on the technical problems of portable and semi-portable batteries.

MR. DAVID N. HUTTON, at his home in Motherwell, Lanarkshire, on February 19, at the age of 49. He was managing director of British National Electrics Ltd., Newarthill, Motherwell, the domestic-appliance subsidiary company of Johnson and Phillips Ltd., Charlton, London, S.E.7. He joined British National Electrics as secretary upwards of 20 years ago and was made general manager in 1948 and managing director in 1953.

CAPTAIN RUPERT JOHN GOODMAN-CROUCH, O.B.E., F.R.Ae.S., F.R.S.A., at Victoria Hospital, Burnley, on February 20, at the age of 63. Mr. Goodman-Crouch, who was associated with Burnley Aircraft Products Ltd., Burnley, Lancashire, was assistant director, Air Ministry, from 1939 to 1940 and deputy-director, Ministry of Aircraft Production, in 1941. Trained at the Breguet Aeroplane Co. he served with the R.N.A.S. and the R.A.F. from 1914 to 1918 and was head of the Airworthiness Department, Royal Aircraft Establishment, Farnborough, from 1922 until 1928.

MR. WILLIAM HISLOP, at Edinburgh Royal Infirmary on February 22. Mr. Hislop was a director of Brown Brothers & Co. Ltd., Rosebank Ironworks, Edinburgh. He became a member of the Institution of Engineers and Shipbuilders in Scotland in 1938.

MR. CHRISTOPHER MARK MAYSON, M.I.E.E., on March 1, at the age of 82. He was station engineer of the Charing Cross Electric Supply Co., St. Martin's Lane, London, W.C.2, from 1899 until his retirement in 1937. An authority on Diesel engines for power generation, he was President of the Diesel Engine Users Association from 1933 to 1934.

ENGINEER REAR-ADMIRAL HERBERT BROOKS MOORSHEAD, C.B., C.B.E., at Plymouth on February 28, at the age of 85. For his services in the war of 1914–18, he was awarded the C.B.E. He retired some 30 years ago, and received the C.B. in 1925.

MR. ROBERT WALTON BROWNE, at Chester on February 27 at the age of 54. Trained at Dublin as a locomotive engineer, he went to the Nigerian Railways in 1925 and became assistant works manager. After returning to this country he joined the staff of Imperial Chemical Industries, Ltd., at Runcorn, and was transport manager there until his death.

FILMS OF INDONESIA AND CEYLON

Oil Prospecting and Diesel-Electric Locomotives

The Brush Aboe Group and the Shell Petroleum Company have each recently presented a programme of films dealing with work in tropical countries. The films shown by the former organisation had Ceylon as their subject and in particular the Ceylon Government Railways, which are being equipped with Diesel-electric locomotives built by members of the group. The Shell films were concerned primarily with oil prospecting in Indonesia, and the programme included "The Search for Oil," which was reviewed in ENGINEERING on December 10, 1954; to this was added a sequel, in which a first exploratory oil well is drilled on the selected site, and also an introductory film explaining the formation of oil in geological terms.

The treatment adopted in this geological study combines animated diagrams with dramatic views of rocks and rock strata; and both the manner in which trapped marine organisms are converted to oil and oil gas, and the action of natural forces in changing the earth's surface are vividly illustrated. The erosive effect of rainfall, for example, is shown in a series of shots cut with increasing rapidity as the movement of mud and water rises to a torrent—a passage reminiscent of "The River," the masterpiece made by Pare Lorentz for the United States Government.

The story begun in "The Changing Earth" is continued in "The Search for Oil," which shows oil prospectors making practical use of geological evidence; in "The Wildcat" the narrative is carried one stage further. This film, like its predecessor, was photographed largely on location in Indonesia but also includes animated diagrams; these reveal what is happening underground while the crew labours rhythmically on the surface. The "star," however, is the derrick, which, seen from many angles, provides an impressive centre to the picture.

During the course of the film, which begins with the "spudding in" of the well, the site is prepared and the derrick erected; drilling begins and different rock formations are penetrated, while the drill string is continually pulled and re-run; each length of casing added is set and cemented until eventually oil-bearing strata are reached; gun perforation then allows the oil to flow up the well, which is finally capped with the assembly of valves known as the "Christmas tree."

These three films, which carry sound tracks and have running times of 9, 31 and 33 minutes, respectively, have all been written and directed by the talented Dutch documentary director Bert Haanstra, and made with the assistance of N.V. de Bataafsche Petroleum Maatschappij, under the general supervision of Sir Arthur Elton. Copies are available on loan in both 35-mm. and 16-mm. gauges, in the United Kingdom from the Petroleum Films Bureau, 29 New Bond-street, London, W.1, and overseas through the appropriate Shell companies. It is expected that a fourth film in the series, entitled "The Oilfield," will shortly be completed.

An attractive film description of Kandy, "The Hill Capital," made for the Ceylon Government, introduced the Brush Group programme, which continued with "To Build an Island's Future," an account of the use of Diesel-electric locomotives in Ceylon. This 15-minute colour film indicates some of the exacting requirements with regard to temperatures, curves and gradients which the new locomotives have to meet, and shows in addition a number of phases in their construction. Sixteen are already in operation and have now travelled nearly a million miles; it is anticipated that the remaining nine will be working within a few months.

In the construction of these locomotives the following companies have taken part: for design and erection, Brush Bagnall Traction, Limited; for Diesel engines, Mirrlees Bickerton and Day, Limited; for electrical equipment, the Brush Electrical Engineering Company, Limited; and for mechanical parts, W. G. Bagnall, Limited; they are all members of the Brush Aboe Group, 32 Duke-street, St. James's, London, S.W.1.

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AIRCRAFT PRODUCTION RESEARCH

That the United Kingdom is neglecting the scientific development of production techniques was the main theme of a lecture entitled "The Scientific Approach and Research in Aircraft Production" given recently before the Royal Aeronautical Society in London by Professor J. V. Connolly, head of the Department of Aircraft Economics and Production, College of Aeronautics, Cranfield. At present only a few hundred engineers were engaged on production research in the British aircraft industry; if more effort were not put into developing new methods of manufacture, the industry would lose ground and Great Britain would become dependent on the United States for aircraft supplies, as we were at present for production ideas and machines.

In the research institutions, such as the Production Engineering Research Association, the Mechanical Engineering Research Laboratory, and the College of Aeronautics, a small amount of work was being carried out on cutting and forming processes and the development of machine tools. Although the total effort was "microscopic" in comparison with that needed, even these modest efforts had shown useful results. To illustrate this point, Professor Connolly then cited some of the recent work at the College of Aeronautics which had aroused considerable interest in industry, including investigations into the suitability of plastic tools for aircraft production; the scientific stretch-forming of light-alloy sheet for aircraft skins; the machineability of titanium and of the Nimonic alloys. Examples were also given of the relation between the number of manhours required and the quantity of aircraft in the production programme. This latter investigation, the lecturer said, facilitated advance planning by the use of generalised statistical data—but the compilation of such data was hampered by the attitude of the industry which too often would not make available their own statistics even if they were kept in a form useful for this purpose.

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INSTITUTION OF ELECTRICAL ENGINEERS

Annual Dinner

Some 1,400 members and guests attended the annual dinner of the Institution of Electrical Engineers, which was held at Grosvenor House, London, on Thursday, February 24, the President (Mr. J. Eccles) being in the chair.

Proposing the toast of "The Institution of Electrical Engineers" the Master of the Rolls (the Rt. Hon. Sir Raymond Evershed) said that that body required no advocate to commend it. Its members never forgot that they belonged to a profession with high standards and that they therefore had an obligation to the rest of mankind as well as to their own consumers. In wishing them every prosperity he asked them to bear in mind the importance of maintaining that pride and integrity which were the qualities of the professional man.

In reply, the President pointed out that engineers were concerned with things and not with people. The laws to which they worked were different from those which the Master of the Rolls administered, being subject to calculation, verification and cross-checking. There was a darker side to the attempts they had made to improve on nature. Nevertheless the balance was on the credit side, since their devices had vanquished toil. If progress was to continue however, they would require more scientists and engineers; and it was necessary to bring this fact to the large number of people who did not realise it.

The toast of "Our Guests" was proposed by Mr. H. Bishop. In reply Lord Citrine referred to that day's increase in the Bank Rate. He said the result would be that the British Electricity Authority would have to pay the bankers £1½ million or possibly £2 million more for the same amount of work. He failed to see how this furthered the doctrine that more production merited more reward.

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FIRST BRITISH 200-MW TURBO-ALTERNATOR

Notable Advance in Design

The British Electricity Authority announce that they have ordered a 200-MW turbo-alternator from the English Electric Company which will, it is believed, be the largest in Europe: it will have an output greater than that of the whole of the generating plant in all but 24 of the present 288 public stations. It will be supplied from a single pulverised fuel-fired boiler, which has been ordered from International Combustion, Limited, and which will have an output of 1,400,000 lb. of steam per hour at a pressure of 2,450 lb. per square inch and a temperature of 1,060 deg. F., with re-heat to 1,005 deg. F.

This plant will be the first of five similar units which, subject to the consent of the Minister of Fuel and Power, will be erected on a site provisionally selected at High Marnham on the River Trent. When completed, this station, with an installed capacity of 1,000 MW, will be the largest in the country and will consume about 2½ million tons of coal a year. It will be designed to operate at high efficiency and thus it is hoped will save the extra 1 million tons per year that would have been required to produce the same amount of electricity in existing stations. It will therefore contribute materially to the better utilisation of the nation's coal resources.

In making this announcement the Authority point out that before the war there were few sets with individual capacities of more than 30 MW; and that with some exceptions the steam conditions did not exceed 600 lb. per square inch and 800 to 850 deg. F. In the six years up to the end of 1953 some 36, 60-MW sets operating at a pressure of 900 lb. per square inch and a temperature of 900 deg. F., were brought into service and most of the units in the programmes for the next year or two are also of this size. In addition, a number of 100-MW sets operating at 1,500 lb. per square inch and 1,050 deg. F. and of 120-MW sets operating at 1,500 lb. and 1,000 deg. F. have been planned.

Along with this increase in the size of the generating sets has gone the introduction of larger and larger boilers. This development has been made possible by advances in design and by the more widespread adoption of pulverised fuel firing. It has also permitted the use of the "unit" system, so that the single boilers associated with the 60-MW sets have an output of 550,000 lb. of steam per hour, those for the 100-MW sets an output of 830,000 lb. per hour and those for the 120-MW sets an output of 860,000 lb. per hour.

A further result of the advances in design that have taken place is that more power can be installed in less space. In fact, while power stations designed in 1948 required 49·4 cub. ft. per kilowatt installed, this had been reduced to 30·5 cub. ft. in 1952, a decrease of 38·3 per cent. This improvement still continues and the new Willington A station, which is scheduled to come into operation in 1957, and will be equipped with four 100-MW sets, will not occupy more than 18·9 cub. ft. per kilowatt, the unit boilers being only partially enclosed.

STUDENT AND TRADE APPRENTICES

COURSES PROVIDED BY SOME ENGINEERING FIRMS

Not infrequently, in discussions about the shortage of technically-trained recruits for industry in this country, comparisons are drawn between the high proportion, in relation to population, of university graduates in the United States and the relatively low proportion in Great Britain. These comparisons are valueless because they are not comparing the same grades. No one will question the high academic status of the leading American universities, but the advanced work which is done in them is post-graduate work. No course equivalent to, say, that leading to an honours degree at Cambridge forms a part of an ordinary degree course in America. The level of attainment which such a degree represents corresponds broadly with that of a Higher National Certificate, or even the Ordinary Certificate. As the United States, with some three times the population of Great Britain, has about ten times the productivity, it would seem that its technical education system is a profitable one. When Professor A. F. Burstall, of King's College, Newcastle-upon-Tyne, stated that "too much emphasis was placed on the requirements of mathematics for engineering students at the universities," he would appear to have been suggesting an approach towards the American university system.

Actually, the difference between British and American procedure is one rather of terminology than of fact. A supply of technically-trained men, equivalent to American graduates, is furnished by the technical colleges and schools, and some brochures recently received make it clear that British firms are alive to the fact. In our issue of October 15, 1954, we referred to publications giving particulars of the engineering-apprenticeship schemes of a number of firms. A further batch may profitably be reviewed. The various pamphlets cover every type of apprenticeship course from those intended for university graduates to those for trade apprentices entering industry direct from school. No doubt, on a purely numerical basis, trade apprentices are the most important class, but from the point of view of the scientific progress of the engineering industry, the more highly-trained recruits occupy first place.

SANDWICH COURSE

Many engineering firms have for long operated graduate-apprenticeship courses and have kept in touch with university appointment boards. The General Electric Company are among the many; they recently introduced a new type of course in which the educational facilities provided by the technical colleges are used to the full. It is a sandwich scheme operated by the firm in conjunction with the Birmingham College of Technology. Boys leaving school at the age of 18 are given five years' training in which full-time sessions of six months at the College of Technology alternate with six-months periods of training in the works. The company pay the students' college fees and give him suitable remuneration to cover his living expenses. Two country houses—Castle Bromwich Hall, near Birmingham, and Coombe Abbey, near Coventry—are used as halls of residence.

This attractive and generous student apprentice course is by no means the only apprenticeship scheme operated by the General Electric Company; it is, however, of special interest in connection with the supply of technicians for British industry. We would not suggest that many, or most, engineering graduates may not make admirable "technicians," but there are large numbers of youths whose inherent abilities, or in some cases opportunities, debar them from reaching graduate level. They correspond to the vast numbers of American graduates who play such an important part in United States industry. In the course of a discussion at the British Association meeting in Oxford last September, from which the above remark by Professor Burstall is quoted, Dr. Willis Jackson said "the main weakness in this country seems to be at the technician level."

Student-apprentice schemes of the type we have been describing would appear to furnish an approach towards the curing of that weakness. Although the General Electric course embodies novel features, it is by no means the only student-apprenticeship scheme in operation. The English Electric Company, for instance, in addition to trade and graduate courses, operates one for student apprentices for boys from grammar or public schools. The apprentices are required to take part-time courses of study and are encouraged to sit for the London University External Degree or other suitable examinations. They may be released for full-time college attendance during the final year. The pamphlet describing the scheme contains the statement that "from the ranks of student apprentices should come the men who will fill most of the middle and senior positions in English Electric."

RESPONSIBLE POSITIONS

The hope and expectation of the English Electric Company are shared by some others. For instance W. T. Henley's Telegraph Works Company, which operates graduate, trade and student apprentice schemes, states in connection with the latter that "student apprenticeships are designed to provide suitable personnel for filling future responsible positions in Henley's." Herbert Morris, Limited, promote the more promising youths from among the trade apprentices to the student apprentice grade, from which "are chosen our future draughtsmen, designers, technical sales representatives, inspecting and maintenance engineers and others who attain more highly responsible positions." Again, it is the policy of the Dowty Group Limited, "to fill executive positions from the ranks of ex-apprentices," and this does not refer to graduate apprentices.

The many training schemes operated by British engineering firms vary in detail and the arrangements in any particular case can be learned only by studying the appropriate brochure. A list of the publications of the firms mentioned in this article is given below. In broad terms, and taking industry as a whole, apprentices are divided into the graduate, student and trade grades. It is not proposed to deal with graduate apprentices here; much has been written on the matter in the past and in any case no engineering graduate with a respectable degree is likely to have any difficulty in entering on a graduate-apprenticeship course should he wish it; he is more likely to have difficulty in choosing from among various offers. In connection with student apprenticeships, however, with which we have been dealing, a matter of interest and importance is that in many cases the more promising trade apprentices may be promoted to the student grade. It is sometimes contended, or pretended, that among the large groups of working-class boys which furnish most of the trade apprentices, there are many with abilities which if cultivated might raise them to the technical level of a university graduate. This claim may be exaggerated, but there are certainly some such boys and the training courses, operated by many firms, in which merit is rewarded by transference to a higher class, provide a means by which inherent ability may be encouraged and developed. There is no reason why a boy leaving school at the age of 16 should not, if he has the capacity, rise to any position. The general manager of the Canadian factory of the Dowty Group is an ex-apprentice.

PART-TIME CLASSES

All engineering firms of any standing encourage their trade apprentices to improve their technical education. The majority make special arrangements to enable them to do so. In a booklet dealing with apprentice training, issued by the Gauge and Tool Makers Association, it is stated that 76 per cent. of the constituent firms of the Association allow their apprentices the equivalent of one full day per week for attendance at classes. Only 17 per cent. allow only such time as is necessary to get to evening classes. The remainder allow half-a-day or less. Two further examples of firms allowing day-release privileges are furnished by Dewrance and Company, and the Richardsons Westgarth Group. An illustration of the extent to which apprentices are taking advantage of educational facilities is provided by the fact that 182 student employees of the Automatic Telephone and Electric Company were presented with monetary awards by the firm for success in technological examinations during 1954.

CRAFT TRAINING

It has been pointed out to us by Mr. Mayfield, the Apprentice Supervisor of Herbert Morris, Limited, that "the vast majority of the trainees are at the craft level and we should not overlook their importance in industry." We trust we have not done so, and a study of the relevant publications of the various firms mentioned above will make it clear that they have certainly not. The existence of the vast army of semi-skilled workers which has been brought into existence by the development of modern mass-production methods has not eliminated the need for a supporting army of craftsmen; it has increased it. The craft training available with different firms naturally varies with their activities. The great range of products manufactured by the General Electric Company and the English Electric Company provide training in a number of different crafts, but the documents mentioned in this article make it clear that care is taken in firms covering a more limited field to enable trade apprentices to become craftsmen; they are not merely turned into semi-skilled specialists with a limited range.

A brochure from Hoover, Limited, contains information about graduate and trade apprentices and a student-apprentice course covering three years. It is of the sandwich type with periods divided between the Perivale factory and the Enfield Technical College. This Hoover document differs, however, from most of the others with which we have been concerned in that it covers schemes for the training of recruits for the commercial as well as the manufacturing sides of the company's operations. The various courses which are operated should offer opportunities to youths whose interests or capabilities are outside the spheres of engineering manufacture or design.

The titles of the publications referred to in this article and the addresses from which they can be obtained are as follows :—

"An Engineering Career." Dewrance and Company, Limited, Great Dover-street, London, S.E.1.

"What About Your Future?" The Dowty Group, Limited, Cheltenham.

"Earning While Learning." The English Electric Company, Limited, Queens House, Kingsway, London, W.C.2.

"Apprentice Training in the Gauge and Tool Industry." The Gauge and Tool Makers' Association, Standbrook House, Old Bond-street, London, W.1.

"Professional Training in the G.E.C." The General Electric Company, Limited, Magnet House, Kingsway, London, W.C.2.

"Henley Student Manual." W. T. Henley's Telegraph Works Company, Limited, 95 Aldwych, London, W.C.2.

"Look to Engineering for Your Future." Herbert Morris, Limited, Loughborough.

"Training for Commerce and Industry." Hoover Limited, Hoover House, 211/213 Regent-street London, W.1.

"Your Future is Marine Engineering. Apprenticeships with Richardsons, Westgarth and Company, Limited." Chief Apprentice and Welfare Officer, Richardsons, Westgarth & Co., Ltd., Northumberland Engine Works, Wallsend-on-Tyne, Northumberland.

Further articles on apprenticeship courses in engineering firms will be published in ENGINEERING from time to time.

BOOK REVIEWS

What Every Engineer should know about Rubber. By W. J. S. NAUNTON. *The British Rubber Development Board, Market Buildings, Mark-lane, London, E.C.*3. (3*s*. 6*d*.)

Although by far the greater portion of the world's rubber, both natural and synthetic, is used in pneumatic tyres, additional fields of application mainly based on rubber itself as a spring material are now well established. In tyres of course, it is air under pressure which acts as the spring, the composite structure of rubber and fabric forming a hard wearing flexible container. The ideas upon which many of these new applications are founded, namely the attachment of rubber to metals and its use as a vibration insulator for internal combustion engines, were patented as long ago as 1862 and 1904 respectively, but it is only within the last 20 years or so that they have become part of engineering technology.

In his book, chemist and Colwyn Medallist Dr. Naunton deals with rubber in mechanical, electrical and chemical engineering. Already an authority in his own right as readers of *Rubber in Engineering* and *The Services Rubber Investigations* (H.M. Stationery Office) will know, he has freely consulted others and drawn from most of the important firms in this country serving these branches of engineering.

The contents include brief information on the preparation of the raw materials, namely: natural and synthetic rubbers, reclaimed rubber and chemical derivatives of natural rubber, together with a description under the chapter heading " Rubber Technology " of the manufacturing processes and operations necessary for the production of rubber components. The principles of " compounding," that is to say the incorporation in the rubber of the many other ingredients required to make it useful to the engineer, are treated, omitting what would be unnecessary chemical detail for this book.

Rubber has many properties of value to the engineer. They are defined and described in fair detail, and those whose measurements are important only to the rubber technologist for quality control are distinguished from those important as design data for the engineer. Tension strength, resilience, resistance to cutting, tearing and abrasion, strength of the rubber to metal bond, thermal, electrical and frictional properties are appraised, and applications are related to the manner in which they avail themselves of these properties. We are reminded that rubber is virtually incompressible and even suffers from the effects of stress concentration and fatigue. To ignore these simple facts is to court disappointing performance or even complete failure.

The remainder of the book, rather more than half, is directly concerned with the uses of rubber in engineering. They are classified under three headings: (1) Vibration Insulation and Isolation (shock absorbers, anti-vibration mountings, dampers and sound insulation), (2) Distortional Systems (flexible couplings, belting, hose, rollers, solid tyres, seals and rubber hydraulics), (3) Protective Systems (protection against corrosion and abrasion, electrical insulation). Numerous drawings and photographs illustrate the text. The uses have examples in almost every industry—automobile, railway, marine, printing, textiles, chemical and electrical—but only one from the aircraft industry. The reason for this may lie in the existence of a special monograph on rubber in aircraft by the same publishers.

There is a useful series of drawings illustrating good and bad features in the design of anti-vibration mountings and rubber bushes, the main theme being avoidance of stress concentration and mitigation of fatigue at the rubber/metal interface.

The final chapter on testing, emphasises the necessity of checking the performance of the finished component by rig test. Three interesting examples are given however, where even rig tests were inadequately designed, resulting in apparently thoroughly checked units failing in service.

The book is clearly and concisely written though the sequence of chapters would have been more systematic had that on " Rubber Technology " (IV) followed upon the collection and preparation of raw natural rubber (I) and the section concluded with Chapter III on the " Properties of Rubber." Chapter II on " Rubber and the Engineer " seems the ideal transition from III to Chapter V on the " Uses of Rubber in Engineering " leaving the final chapter (VI) on " Testing and Specifications " unchanged. Dr. Naunton's arrangement, however, makes it less easy for the busy engineer to omit *en bloc* the purely rubber section which must be read to obtain full appreciation of the subject.

This small book packed with useful information is rightly free from mathematical and chemical detail, and is obviously intended to be of wide appeal. The specialist will need to know a lot more than it contains: many others can scarcely afford to know less.

The Light Metals Handbook. By GEORGE A. PAGONIS. *D. Van Nostrand Company, Incorporated, 250 Fourth-avenue, New York 3, N.Y., U.S.A.* (8·50 dols.); and *Macmillan and Company, Limited, St. Martin's-street, London, W.C.*2. (63*s*.)

Any metallurgist or engineer seeking data on the characteristics and properties of an alloy usually becomes involved in a task of disconcerting magnitude. After searching all apparently useful sources, he may have obtained figures from trade literature, standard reference books, published papers and from the myriads of specifications originating from various bodies, but will then probably find that the items of data do not dovetail together. The result of his work will be a very incomplete answer to his original problem. This picture has not been overdrawn in any way, for little has been done to produce reference books presenting, in considerable detail, information on the properties of materials.

Many will agree that a desirable step in the right direction would be to publish collections of information on groups of materials. This has been done usefully for steels and now also for light alloys, for Mr. Pagonis has restricted his book to the alloys of aluminium and magnesium.

A first reaction on seeing *The Light Metals Handbook* is to admire the novelty of its make-up. The work is in two volumes, one containing the text and the other composed solely of tabulated matter, but the unusual feature is that both volumes are normally held as one by an ingenious envelope in the binding. The purpose of the two volumes becomes clear when the reader begins to look up information, for he then has available a useful detailed description of any particular alloy while, without having to turn over pages or use book marks, he has, in the other volume open before him, the various tables of properties.

Looking through the books makes the reader admire the clear layout of both text and tables, but this does not prevent a sense of dismay on seeing that there is no index. The contents pages must be relied upon to indicate where required items are to be found.

The book has been written for the American user and consequently loses a great deal of its value for the British engineer unless he is able to find a United States alloy similar in type to that in which he is interested. This is facilitated to some extent by grouping the various alloys by their basic compositions where they are listed in the contents pages. It is somewhat surprising to find the first chapter of text consists of " Safe Precautions and Precautionary Rules for Magnesium." Although useful, the information given here seems somewhat out of place.

The tables contained in Volume 2 show an unfortunate omission, as no references are given to the sources of the various figures quoted. Many users of " The Light Metals Handbook " will wish to augment the basic data by looking up the source material. Perhaps, however, Mr. Pagonis has decided that the extra complications involved in including a very long table of references could not be justified.

TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Electric Furnace. SOCIETÀ FORNI LUBATTI, Via PO. 31, Turin, Italy. Description of the Lubatti electric furnace and process for smelting fine ores. The furnace is of the open-ball type, the graphite electrodes, in lump form, suspended from water-cooled arms, being immersed in a layer of fused slag floating over the molten metal and lying below a constantly renewed charge of mixed fine ore and coal. Reprint of paper, in French but with summaries in Italian, English, French and German, presented at 3rd International Electrothermic Congress, held in Paris from May 17 to 23, 1953.

Silver Plating. JOHNSON, MATTHEY & CO., LTD., Hatton Garden, London, E.C.1. Practical description of the various operations involved in silver plating, indicating suitable methods for most requirements and giving warnings of possible difficulties. It is intended as a guide for newcomers but it is believed that experienced platers may gain new and helpful ideas from it. Cloth-bound book of 36 pages.

Clad Steels. COLVILLES LTD., 195, West George-street, Glasgow. Plates consisting of a layer of cladding metal bonded to a selected thickness of carbon or low-alloy steel, are manufactured under closely controlled conditions. An illustrated publication dealing with the manufacture, properties, testing, welding, and fabrication of Colclad stainless-steel, nickel and Monel-metal clad steels. Many applications are indicated.

Excavator Crane and Straddle Truck. HYSTER CO., 2902 N.E. Clackamas-street, Portland 8, Orgeon. Crane boom fitted to caterpillar D6, D7 or D8 track-type tractor: ancillary equipment converts into shovel, backhoe, dragline, crane, clamshell or pile driver. Twenty-page illustrated booklet. Straddle truck, 20,000-lb. capacity; package dimensions, 78 in. high by 76 in. wide. Specification leaflet.

Refractory Strainer Cores. MORGAN CRUCIBLE CO., LTD., Battersea Church-road, London, S.W.11. Ceramic strainer cores made by Coupe and Tidman Ltd., Treforest Trading Estate, Pontypridd, Glamorgan, in association with the Morgan Co. The use of these strainer cores in the foundry gives greater control during pouring and improves efficiency. Illustrated explanatory leaflets.

Drip Regulator. BORO' LABORATORIES AND APPLIANCE CO., LTD., 1 Station Buildings, Catford, London, S.E.6. The Condesco is a drip regulator or dispenser for liquids having a capacity of 40 fluid oz., and a working range of from 2 to 180 drops a minute. Illustrated leaflet.

Steel Castings. THE NORTH BRITISH STEEL FOUNDRY LTD., Bathgate, near Edinburgh. Notes on the design and the purchase of steel castings and brief particulars of the firm's equipment and facilities. Illustrated catalogue.

Arbor Press. SALESCOPE, 32 Church-street, Lancaster. Maximum arbor diameter 3 in., arbor length 14 in., admits work of diameter 16 in.; leverage 28 : 1 ; also suitable for light riveting, embossing, folding, bending. Illustrated leaflet.

Vehicle Servicing Unit. AUTO DIESELS, LTD., Uxbridge, Middlesex. Unit comprising motor driven pumping apparatus for supplying fuel, lubricant, and water, air compressor with air line, and battery charger. Illustrated leaflet.

Telegraph Relay. STANDARD TELEPHONES AND CABLES LTD., Aldwych, London, W.C.2. Side-stable polarised relay excitation range 20 to 200 amp.turns. Two watts continuous rating. Leaflet C/2018 gives details.

Alternating-Current Marine Motors. LAURENCE, SCOTT AND ELECTROMOTORS LTD., 431 Grand Buildings, Trafalgar-square, London, W.C.2. Standard range of alternating-current motors for marine installations. List No. 132.

Control Boards. A. REYROLLE & CO., LTD., Hebburn, Co. Durham. Examples of control boards, consoles and panels, with diagrams of control-room layouts. Full dimensions of separate units embodied. Large illustrated booklet, No. 1248.

Petrol-driven Chain Saw. J. CLUBLEY ARMSTRONG DANARM LTD., Abford House, Wilton-road, London, S.W.1. " Whipper " lightweight one-man petrol-driven chain saw. Illustrated leaflet.

Airbreak Switchgear. A. REYROLLE & CO., LTD., Hebburn, Co. Durham. Flame-proof air break products—switchgear, contactors and transformers. Leaflet gives brief details.

BOOKS RECEIVED

Some of the books noticed in the Books Received column are selected for extended review in later issues of ENGINEERING.

Farm Implements. U.S. Case Study Data on Productivity and Factory Performance. Prepared for the Foreign Operations Administration, Industrial and Technical Assistance Division, by the United States Department of Labor. Distributed in Great Britain by the *British Institute of Management*, 8 *Hill-street, London, W.*1. (10*s.*)

The series of reports by the U.S. Department of Labor is designed to help production engineers and managers in this country. This factory performance report deals with the manufacture of harrows, cultivators, ploughs and mowers. The parts required and the methods of assembly are described in detail, and readers are advised of the best way of using the report.

Conference on Works Transport. *British Iron and Steel Research Association*, 11 *Park-lane, London, W.*1. (5*s.*)

This report contains all the papers and the ensuing discussions at the conference held in July last year and organised by the Plant Engineering Division and the Operational Research Section of B.I.S.R.A. Between them the ten papers cover the organisation of works transport both within and without the works, with special regard to the choice of equipment for internal use and co-operation with British Railways and the road haulage industry externally. A brief report of the conference was published in ENGINEERING, vol. 178, pages 273 and 300 (1954).

Building Construction. By W. B. MCKAY. Three volumes in one. *Longmans, Green and Company, Limited*, 6 *and* 7 *Clifford-street, London, W.*1. (45*s.*)

A comprehensive text-book intended for students preparing for the examination of the Royal Institute of British Architects and allied professional bodies, and for the national certificates and diplomas in building. The present volume is an omnibus edition of the author's three books and has been designed for convenient reference by students who have completed their courses. Copiously illustrated by sketches of details, it gives descriptions of the practices now adopted by each of the building trades for both domestic and industrial buildings.

Corrosion Resistant Floors. Part I: Design Considerations. Building Research Station Digest No. 73. *H.M. Stationery Office, Kingsway, London, W.C.*2. (3*d.*)

The floor finishes in industrial buildings are provided primarily to protect the structural floor from factory conditions, e.g., from foot and truck traffic, impact loading and corrosive liquids. This digest discusses the particular problem of corrosion resistance required by reinforced-concrete floors and is concerned particularly with the design of the floor system as a whole—the provision of slopes and drainage outlets. Finishes will be described in a later publication in this series.

Safety in Industry: An Introduction to the Protection of Personnel. By D. I. MACFARLANE. Published for " Machine Shop Magazine," by *Iliffe and Sons, Limited, Dorset House, Stamford-street, London, S.E.*1. (7*s.* 6*d.*)

Details of a number of expedients whereby plant and premises may be made safer and personal protective measures made more effective are given in this booklet which forms a general introduction to the subject of industrial safety. The contents include: dust and fume control, guarding rotating machinery, press guards, dermatitis, eyes, ionising radiations, protective clothing, lighting and flooring. Special emphasis is laid on the dangers of rotating machinery and on the need for guards on presses. Modern protective clothing, boots and helmets are described particularly with respect to their value against dust, fumes and harmful radiations.

Engineering Dynamics Vol. I: Theory of Elasticity. By C. B. BIEZENO and R. GRAMMEL. *Blackie and Son, Limited*, 17 *Stanhope-street, Glasgow, C.*4. (50*s.*)

This book is a translation of *Technische Dynamik* originally published in Germany in 1939, as a text book for post-graduate students tackling the problems encountered in practice and in research. Throughout, it is assumed that the reader is familiar with elementary mechanics (to engineering degree standard) and the relevant mathematics. The problems dealt with relate particularly to mechanical engineering and especially to engine design, and have been included only if the solution to the problem can be applied in practice, the details having been evaluated numerically with a tolerable amount of arithmetic. Methods of solution are given prominence and about half of the book is devoted to a study of methods, such as aids to calculations (harmonic analysis), numerical solution of boundary problems and experimental methods of strain and stress determination. Particular problems discussed include: the fundamental laws relating to stress and strain in plane and three-dimensional states, energy and reciprocal theorems, and stress functions of two-dimensional stress problems.

The Strength Properties of Plywood. Part 2: Effect of the Geometry of Construction. By W. T. CURRY. Forest Products Research Bulletin No. 33. Published for the Department of Scientific and Industrial Research by *H.M. Stationery Office, Kingsway, London, W.C.*2. (2*s.*)

The bulletin describes an investigation and gives the results relating to the calculation of the bending, tension, compression and shear strengths of plywood constructions. From the results, equations are formulated which can be used for any species of wood in laminated form in such members as box and web-type girders, panel floors and walls, ship planking and concrete shuttering.

Handbook of the Collection Relating to Heat and Cold. Part II: Catalogue of Exhibits with Descriptive Notes. By J. A. CHALDECOTT. Publication of the Science Museum. *Science Museum, South Kensington, London, S.W.*7.; and *H.M. Stationery Office, Kingsway, London, W.C.*2. (3*s.*)

About one half of the Science Museum collection illustrating heat and thermal instruments is described in detail; subjects include thermal expansion, calorimetry, change of state and critical state, the nature of heat, heat transfer, refrigeration, and very low temperatures.

Control of Stocks for Distribution: The Practice of Ten Companies. Management Economics Series No. 2. *British Institute of Management*, 8 *Hill-street, London, W.*1. (5*s.*)

Stocks for distribution must be controlled to ensure that funds are not tied up in unsaleable goods, and that consumers' demands can be readily satisfied. The practice of ten companies on this matter are described in detail in this B.I.M. publication. Basic characteristics of each company are indicated for comparison with readers' own firms and stock control problems.

Reports of the College of Aeronautics, Cranfield. *The Librarian, College of Aeronautics, Cranfield, Bletchley, Buckinghamshire.* (5*s.* each):—

An Experimental Investigation into some of the Problems Associated with Stress Diffusion in the Vicinity of Chordwise Cut-Outs in the Wing, and a Comparison with Existing Theories. By Lt. LAVERNE W. BROWN. Report No. 83.

This report describes an investigation into the build-up of stress in the corners of a panel adjacent to an opening, with a search for effects hitherto ignored or unknown. Tests were made on a large stringer-skin panel bounded by constant-area edge members and subjected to concentrated equal end loads. The dimensions of the panel were typical of modern practice. Variations were made in the lateral stiffness of spar booms, the method of attaching the end rib to the spar, and the loading between spar and sheet. The tests showed conclusively that the shear stresses were not only finite in the vicinity of the corner and less than those predicted by existing theories, but that in most cases the shear stress fell off towards zero. The author concludes that there is at present insufficient knowledge to enable designers to choose an optimum design.

Longitudinal Stability Characteristics and Damping in Pitch of Delta Wings. By W. B. MCCARTER. Note No. 11.

In this paper the usual approach to longitudinal stability analysis is adopted but particular attention is paid to those elements that contribute to damping. Two delta wing aircraft of 45 deg. and 60 deg. sweep are considered and their derivatives and the coefficients of the stability quartics are obtained over a range of Mach numbers through the transonic range. An analysis is made of the damping of the short period oscillation in each case. Various methods of improving damping are discussed briefly and some simple examples of response are included.

The Calculation of the Wave Drag of a Family of Low-Drag Axi-Symmetric Nose Shapes of Fineness Ratio 4·5 at Zero Incidence at Supersonic Speeds. By G. B. MARSON. Note No. 10.

In this paper the pressure coefficients of a particular family of convex logarithmic projectile nose shapes in which the nose angle is an important parameter have been calculated over a range of supersonic Mach numbers using a rapid approximate method developed by Zienkiewicz. The results are compared with those for other well-known minimum drag shapes, and the optimum shapes for each Mach number are deduced.

The Testing of High Speed Internal Combustion Engines: With Special Reference to Automobile and Aircraft Types, including Gas Turbines. By ARTHUR W. JUDGE. Fourth edition revised. *Chapman and Hall, Limited*, 37 *Essex-street, London, W.C.*2. (75*s.*)

In the fourth edition the section on measurement of brake horse-power has been rewritten to include accounts of most recent types of brakes and dynamometers ; standard test formulae taking into account atmospheric pressure, temperature, and humidity variations are given. A new section deals with testing of gas turbines used in aircraft. The whole book has been revised and brought up to date.

Fiberglas Reinforced Plastics. By RALPH H. SONNEBORN. *Reinhold Publishing Corporation*, 430 *Park-avenue, New York* 22, *N.Y., U.S.A.* (4·50 dols.); and *Chapman and Hall, Limited*, 37 *Essex-street, London, W.C.*2. (36*s.*)

This book is a summary of information available up to 1954 on glass reinforced plastics. It has been written for executives in the materials industries, and for design engineers; the treatment demands no deep knowledge of chemical engineering. The materials for glass reinforced plastics, various processes of manufacture, properties, and design methods based on experience are described. A contributed chapter deals with the theory of design using glass reinforced plastics.

Milling Plants in Canada. Part I: Operators of Concentrating Mills Treating Metallic Ores. Part II: Operators of Plants Treating Industrial Minerals. *Department of Mines and Technical Surveys, Mines Branch, Mineral Resources Division, Ottawa, Canada.* (25 cents.)

Lists of firms engaged in the concentration and beneficiation of metallic ores and other industrial minerals by such processes as crushing, grinding, screening and flotation are given in tabular form. The information furnished includes the name of the firm and the address of its head office, the situation of the mineral-treatment plant and its daily rated capacity, and the nature of the process employed.

The Design of Power Plant Ducting. By H. S. FOWLER. Report No. ME-208 of the National Research Laboratories, Canada. *National Research Council of Canada, Ottawa, Canada.* (No price given.)

This report deals with the aerodynamic design of power plant ducting, including in that term both pipework and passages in cast components. The aim is to minimise pressure loss, to obtain uniform flow distribution and to produce a form mechanically suited to the machinery. The treatment is both theoretical and practical and there are a number of illustrations.

Alternating-Current Machines. By A. F. PUCHSTEIN, T. C. LLOYD and A. G. CONRAD. Third edition. *John Wiley and Sons, Incorporated*, 440 *Fourth-avenue, New York* 16, *N.Y., U.S.A.* (8·50 dols.); and *Chapman and Hall, Limited*, 37 *Essex-street, London, W.C.*2. (68*s.*)

While the form of this book has not been greatly changed by revision, the approaches to the theory of some of the machines have been modified. For instance, the treatment of equivalent circuits and vector diagrams has been changed, the methods of calculating the cross-axis voltage of synchronous machines have been developed, and equations describing the oscillation of synchronous motors have been included. Material has been added on adjustable speed drives and rectifiers, and the nature of short-circuit currents in alternators is explained by the use of the constant flux-linkage concept.

Cheyenne Mountain Tropospheric Propagation Experiments. By A. P. BARSIS, J. W. HERBSTREIT and K. O. HORNBERG. U.S. National Bureau of Standards Circular 554. *The Superintendent of Documents, U.S. Government Printing Office, Washington* 25, *D.C., U.S.A.* (30 cents.)

In order to study the propagation through the troposphere of very-high and ultra-high frequency radio waves, stations have been set up by the Central Radio Propagation Laboratory on Cheyenne Mountain. This publication records the results of tests at frequencies varying from 92 to 1,046 Mc/s, with continuous recording. The results are analysed and related to the Booker-Gordon theory as extended by Staras.

The Engineering Outlook—9

SHIPBUILDING IN BRITAIN

FLUCTUATIONS IN WORLD MARKETS

British shipbuilders have reason to feel much more optimistic than they did a year ago. Output of merchant vessels, no longer restricted by material shortages, reached 1·4 million tons in 1954, the highest figure since 1930, and with an even higher total likely for 1955, full benefit is at last being derived from the improved building facilities and modern techniques which have been introduced since the war.

The sharp upward trend in shipyard activity is shown in Figs. 1 and 2 and Table I taken from Lloyd's Register Shipbuilding Returns. It is equally important that the steady fall in orders for new ships now seems to have been arrested. Admittedly the total order book is now down to 4·5 million gross tons compared with the peak of 7 million tons in mid-1952; but of a total of 600,000 tons of new orders booked in 1954, 300,000 tons were placed in the last quarter of the year—which means that the flow of new contracts is at last beginning to match the rate of completions. As a result of the great improvement in the fortunes of the shipping industry in recent months, a further increase in the volume of new orders may perhaps be expected. The Chamber of Shipping index of tramp shipping freights (voyage charter 1952 = 100) which had fallen to 71·5 in December, 1953, had recovered to 115·5 in December, 1954. Certainly there was a slight fall to 115·1 in January, 1955, but the fact that time charter rates have continued to advance—to 114·6 in January, 1955, compared with 109·0 in December, 1954, and 57·8 in December, 1953—is very encouraging for the future of British shipping. Second-hand war-time Liberty ships which could not find buyers at £175,000 twelve months ago, can now readily fetch £250,000.

While prosperity must naturally encourage orders for new tonnage, there still remain some obstacles to the replacement of the large number of over-age ships on the United Kingdom register with efficient modern vessels. Of a total merchant fleet of 16·3 million tons, 2·5 million tons are 20 years old or more, and, in addition, there is an even larger volume of war-time tonnage of the Liberty type which cannot be classed as efficient by modern standards. Moreover, the position is much worse if only dry-cargo tonnage is considered. Of a total fleet of 10·9 million tons, 1·7 are over twenty years old—and after making allowances for the war-built vessels, it seems that nearly one-third of the total dry-cargo fleet could be replaced with advantage. Equally serious for the future of the United Kingdom as a maritime power is the steady decline in the proportion of the British mercantile marine to the world fleet. Whereas in 1939 it accounted for 27·1 per cent. of world tonnage, it accounted for only 21·9 per cent. in 1949 and 19·4 per cent. in 1954.

COSTS AND COMPETITION

If the situation is to be remedied, a satisfactory solution will have to be found to a number of problems at present confronting shipowners. One problem is to find funds to buy new ships at present-day prices, when accumulated depreciation on the ships they are replacing may be less than one-third of what is required. The 20 per cent. investment allowance instituted last year is a useful measure, but does not go far enough. Shipowners abroad have sometimes the positive incentive of direct Government assistance to acquire new vessels, the prices of which may also be kept down by subsidies paid to shipbuilders. Other factors which discourage the British shipowner from replacing his fleet include the growing flag discrimination abroad; the increasing delay in turn round in ports which can greatly diminish the advantages of efficient tonnage; and above all the continuing rise in shipbuilding and repairing costs.

The rise in shipbuilding costs is not, of course, due to the shortcomings of shipbuilders, but must be attributed largely to the rise in prices of shipbuilding materials. These, as well as the increased cost of shipbuilding labour, have been to some extent offset by improved shipbuilding methods. The scale of re-organisation is considerable. One of the medium sized shipbuilders, the Caledon Shipbuilding and Engineering Company, of Dundee (output 29,000 tons in 1954), recently announced a re-organisation programme involving the extension of welding and prefabricating facilities and the erection of larger cranes, costing £400,000. Unfortunately, restrictive labour practices too often make it difficult to derive full advantage from these re-organisation schemes, and the hold-ups caused by the rigid and often illogical demarcation of jobs in shipbuilding are perhaps more serious for their effect on costs than the increases in the wages bill. In some of the Continental yards two and three-shift working has greatly increased productivity, reduced delivery periods, and has greatly reduced the risk of quoting fixed prices. Some of the foreign yards who have been particularly successful in obtaining export orders, have also the advantage that they can obtain their steel at a price fixed when they book a new order. British shipbuilders on the other hand have to pay the prices ruling at the date of delivery. It is not surprising, therefore, that British builders have lost orders even from British owners to Continental yards. Both the Blue Funnel Line and the Currie Line have placed orders in Germany. The Currie Line, who had recently taken delivery of a vessel from British yards at a higher cost and some months later than had been anticipated, naturally welcomed the German offer to supply two cargo motor vessels of 1,300 tons deadweight at a fixed price with delivery well within the year. The British competitive position will improve greatly as British and Continental order-books begin to level up, and the Continental yards lose their present delivery advantages. The reduction in the world order book from 16 million tons three years ago to about 14·8 million tons was due very largely to the fall in contracts placed with British and United States yards; and, since the flow of new orders revived in the second half of 1954, the Continental yards have received considerably more proportionately than British yards. During 1954 German shipbuilders booked new orders amounting to about 750,000 tons (of which nearly 60 per cent. was on foreign account) and the total German order book is now about 1·3 million tons—enough to keep the yards busy until about 1957. French shipbuilders, who enjoyed a boom in export orders in January this year, when contracts for 40 ships of 240,000 tons were placed, attributed their success partly to the fact that German order books had filled up rapidly in the last months of 1954. The French shipbuilders, who booked two British orders for cargo ships of 10,000 tons, can still offer delivery towards the middle of 1956, compared with early 1957 for some German yards, and perhaps somewhat later in that year for many British yards. Other countries which have received large orders in recent months are Sweden, where a record output of 500,000 tons in 1954 reduced the total order book by only 4,000 tons; the Netherlands, where the volume of work in hand is now actually higher than in 1953; and Italy, where shipbuilders have been particularly fortunate in attracting orders for United States tonnage. In the United Kingdom, the relatively small volume of orders for export is disturbing. At the end of 1954 (see Table II adapted from Lloyd's Register Shipbuilding Returns), of a total of 2·14 million tons under construction in British yards, 1·36 million tons were on home account, which leaves only 780,000 tons, or 36 per cent., for exports. The German export proportion was 52 per cent. Particularly disappointing from the British point of view is the low proportion of dollar orders which at the end of 1954 amounted to only 13 ships of 80,313 tons: at that time, there was a total of 164 new vessels of 1·67 million tons of United States shipping on order outside the United States, including 34 in Trieste and Italy, 32 in Japan and 29 in Germany.

FOREIGN YARDS SUBSIDISED

The present low volume of export orders in the United Kingdom and the high volume abroad is to a large extent simply a function of the relative delivery positions, and some levelling out may shortly be expected. Nevertheless, foreign yards are bound to hold some of the

TABLE I.—UNITED KINGDOM : SHIPBUILDING ANALYSIS

—	Commenced		Launched		Completed		Under construction		Preparing	
	No.	Tons	No.	Tons	No.	Tons	No.	Tons	No.	Tons
1953—March	51	305,343	47	227,691	64	310,821	323	2,132,903	288	2,454,894
June	61	350,323	62	399,438	65	356,788	317	2,123,565	274	2,391,281
September	47	289,233	57	323,414	47	218,967	316	2,190,329	273	2,286,174
December	55	334,451	55	366,145	57	363,687	313	2,173,709	260	2,157,830
1954—March	65	401,143	51	314,189	53	403,613	323	2,175,760	249	1,921,640
June	66	356,442	63	350,340	60	345,872	328	2,195,085	244	1,691,035
September	53	250,453	62	395,148	65	389,436	316	2,058,457	232	1,579,477
December	75	437,376	75	350,632	64	356,736	327	2,140,752	233	1,491,493

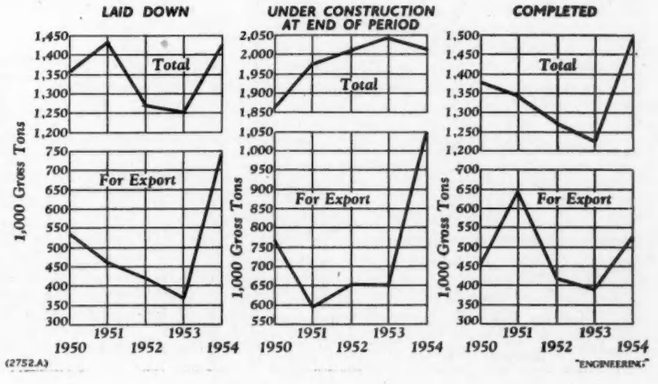

Fig. 1 Merchant shipbuilding in the United Kingdom: the data relate to vessels of 100 gross tons and over. Output rose during 1954, and from the trends during the last quarter of the year it appears that both output and orders will rise in 1955.

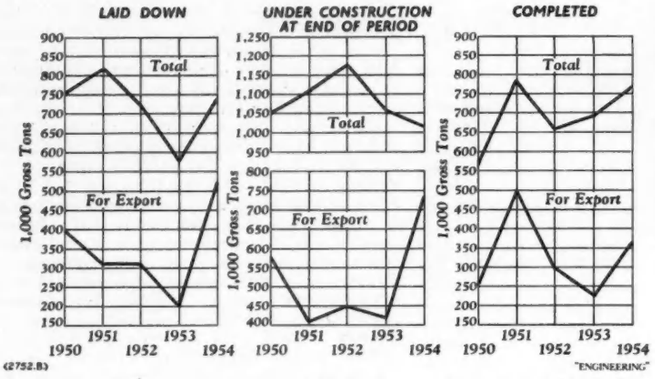

Fig. 2 Tanker construction in the United Kingdom: the data relate to vessels of 1,600 gross tons and over. It appears that the end of the tanker boom has not yet been reached, nor the limit to the size of tankers.

ground gained. Many have doubled their output since 1938. German shipbuilders, who launched 249,000 tons in 1929 and 481,000 tons in 1938, had an output of 963,000 tons in 1954; Sweden produced 535,000 tons compared with 210,000 tons in 1938; the Netherlands 404,000 tons compared with 240,000 tons—and so on. The United Kingdom tonnage has risen by only about 41 per cent. to 1·41 million tons. Subsidies have accounted for much of the growth of shipbuilding capacity abroad. German shipbuilders have hitherto had the advantage of tax regulation known as 7D, which permitted German business men to draw a tax-free income from money invested in shipbuilding. Half of the £200 million devoted to the reconstruction of German shipyards has been provided under the 7D clause. This regulation was repealed at the end of 1954, but not without protest from German shipbuilders. The latter still enjoy the benefit of special low-interest Government loans: in the current financial year it is expected that loans amounting to £4 million, repayable at 4 per cent. over a period of 16 years, will be provided. With the loan of more than £1 million, the former Hamburg shipyard of Blohm und Voss is in production again. German yards have also had cheap steel. In the spring of 1954 they were granted a rebate of £4 4*s.* per ton on steel plate for export orders. With rising demand for steel this subsidy was cut by half in November, and may now be withdrawn altogether.

LARGER CARGO VESSELS

Government support is not the only or perhaps even the main factor behind the success of German shipbuilding. The simple fact that the German yards are capable of handling very large vessels was sufficient to ensure their participation in the tanker boom. German output of tankers in 1954 was 443,840 tons gross, compared with 714,300 tons for the United Kingdom. Of the total output in 1954 of 167,000 tons by the largest German shipyard, the Kieler Howaldswerke—second in the world only to the Newport News Company of the United States (191,000 tons)—90 per cent. comprised tankers for Mr. A. S. Onassis and Mr. S. Niarchos. The largest tanker in the world, the Al-Malik Saud Al-Arval, was completed about three months ago by the Hamburger Howaldswerke. This vessel will, however, eventually take second place to two on order for Mr. Niarchos with Vickers-Armstrongs Limited of Barrow. Neither the end of tanker boom nor the limit to the size of tankers appears yet to have been reached. As may be seen from Table III taken from Lloyd's Register shipbuilding returns, there are at present 1·12 million tons of tankers under construction in British yards: admittedly, there has been a slight fall from the peak in 1952 and the trend is likely to continue downwards, but tankers still consitute a high proportion of the orders recently received by British and world shipyards. A number of the new tankers recently ordered are over 35,000 tons deadweight, and, according to the report of the Annual Meeting of the American Bureau of Shipping, the indications are "that the existing 45,000 deadweight-ton vessels will be succeeded by larger vessels." The trend to larger sizes is not confined to tankers. Three of the most remarkable ships launched in 1954 were ore-carriers of 60,000 tons deadweight, launched in Japan for National Bulk Carriers Incorporated. An increasing number of large ore-carriers is being constructed and more are in prospect.

The size of passenger vessels, on the other hand, is not increasing; a number of factors, including competition from air-travel, have greatly lessened the attractions of the very large luxury passenger liner. Nevertheless, there is a substantial demand for ships of 20,000 to 30,000 tons gross. In 1954, British output included four passenger vessels totalling 94,588 tons. The Italians, who launched the Cristoforo Colombo of 29,000 tons gross in 1953, have received an order for the Gripsholm of 24,000 tons for the Swedish America line. British companies had submitted tenders for the vessel, but it was not surprising that their prices compared unfavourably with that of the heavily subsidised Italians. The French, who have a system of shipbuilding subsidies, through which costs are brought down to a level on which their yards are competitive with British and other Continental yards, are not to be deterred by the heavy capital outlay or economic trends from undertaking the construction of a passenger liner of 50,000 to 60,000 tons. A credit of £4·4 million has been voted by the National Assembly to enable work to begin, and the total cost of the liner, which will eventually replace the Ile de France, is likely to be about £30 million.

JAPAN AND THE UNITED STATES

Japan has hitherto had one of the most heavily subsidised shipbuilding industries of the world. The ship-sugar link system whereby shipbuilders were granted sugar import licences, which they could dispose of at a handsome profit, enabled them to obtain a premium of 10 to 15 per cent. on the price paid for their ships. According to the *Journal of Finance and Commerce*, tanker contracts for export were being concluded at 115 dols. per ton, whereas the lowest economic price was 130 dols. per ton. In consequence, foreign orders for 30 vessels of 300,000 tons were booked towards the end of 1954. The sugar-link system was officially revoked in November, and Japanese shipbuilders have expressed considerable concern about the future of foreign orders. It seems likely, however, that the Japanese Government will find other ways of supporting the shipbuilding industry—perhaps by a subsidy on steel which on the average costs about 21 dols. per ton more than in the United Kingdom. According to one report, the Government intend to set aside a considerable sum in their next budget for this purpose. Whatever the future of export orders, Japanese builders are assured of a useful volume of home orders; under a five-year programme, 900,000 tons of new shipping are to be built for the Japanese merchant fleet (at present 3·3 million tons) between April, 1955, and March, 1959.

United States yards have not so far participated in the general upsurge of new orders. The tonnage of seagoing vessels under construction in that country fell from 611,000 tons in June, 1953, to 88,000 tons in December, 1954. It is not, therefore, surprising that Congress is being asked to approve a programme of subsidies which will assist both the American shipbuilding and shipping industries. According to the American Bureau of Shipping the United States privately-owned merchant fleet "contrary to the trend in all other countries, is now at a post-war low." The Maritime Administration propose an expenditure of 400 million dols. to maintain employment for 35,000 workers in the larger United States shipyards. The programme includes the building of four passenger-cargo liners, 10 tankers for private concerns, 19 tankers for the Navy as well as the modernisation of 62 ships. The passenger cargo vessels will cost 95 million dols., of which the Government will find 44·5 million dols. The privately-owned tankers will be built under a "trade-in" scheme which will enable shipowners to sell two older tankers to the

TABLE II.—World Shipbuilding: Gross Tonnage Under Construction

—	December, 1953				December, 1954			
	For home owners		Total		For home owners		Total	
	No.	Tons	No.	Tons	No.	Tons	No.	Tons
Great Britain	223	1,568,828	313	2,173,709	239	1,366,393	327	2,140,752
Other Commonwealth countries	38	177,875	39	179,577	43	111,181	44	117,181
Belgium	9	55,939	26	142,459	6	38,042	17	110,868
Denmark	25	126,700	29	143,880	23	97,767	30	130,533
Finland	—	—	25	36,946	—	—	29	49,202
France	38	304,612	48	423,081	46	352,894	55	449,096
Germany	88	287,253	140	633,904	132	370,176	204	772,012
Italy	38	347,834	42	352,404	39	151,609	42	195,189
Japan	71	287,255	79	381,807	35	173,685	47	376,565
Netherlands	72	171,420	141	490,989	90	377,241	136	529,679
Norway	49	175,935	49	175,935	54	194,408	54	194,408
Sweden	28	164,968	56	408,748	25	146,831	65	433,191
U.S.A.	42	434,177	49	555,782	13	80,313	15	99,568
Other countries	100	195,655	100	195,655	103	249,203	104	256,003
Total	821	4,298,451	1,136	6,294,876	848	3,709,743	1,169	5,854,247

TABLE III.—United Kingdom: Shipbuilding Analysis by Types of Vessel. (December, 1954)

—	Commenced		Launched		Completed		Under construction		Preparing	
	No.	Tons	No.	Tons	No.	Tons	No.	Tons	No.	Tons
Passenger / Passenger and cargo	2	30,740	3	31,800	—	—	21	242,825	5	21,180
Cargo liner	17	111,080	16	89,255	9	53,345	80	554,476	75	536,633
Cargo tramp	5	26,050	4	27,610	11	61,730	23	139,050	23	155,300
Oil tanker	20	254,820	16	186,632	17	223,840	86	1,123,008	59	721,460
Collier	1	3,400	2	4,195	2	4,481	9	25,542	8	22,940
Coaster	5	2,817	2	1,750	4	4,916	17	16,677	7	8,610
Miscellaneous	25	8,469	32	9,390	21	8,424	91	39,174	56	25,370

Government and obtain a financial credit towards the cost of a modern vessel. Another programme which could have important consequences is a research project to increase the speed of Liberty ships from 10 to 18 knots. At present there are about 14·25 million tons gross of such vessels laid up in the United States reserve fleet. This compares with 90·92 million tons for the total world merchant fleet.

PROPULSION BY GAS TURBINE

Despite the progress made abroad in recent years, the quality of British ships is unsurpassed, and British ship-builders are still in the van of technical development. They are certainly ahead in the application of the gas turbine to marine propulsion. The Auris, a 12,500-ton tanker of the Anglo-Saxon Petroleum Company, has now had more than five years' service with a gas turbine engine. This has operated with considerable success and the Auris which has hitherto also had three Diesel engines, is now to have these replaced by a single gas turbine of 5,300 brake horse power. An outstanding advantage of the gas turbine in service has been freedom from vibration which will make for greatly reduced wear and tear. The transmission has so far been electrical, but a direct mechanical system is to be tried. Gas turbine development is not being neglected in other countries. In Germany, for example, the Deutsche Werft of Hamburg have a working contract on gas turbines with the Swiss concern Escher Wyss and the German A.E.G. company. The Japanese have had an experimental gas turbine of 500 brake horse power operating in a training ship, the Hokuto Maru of 1,600 tons. This turbine, which was built with the aid of a Government subsidy by the Mitsubishi Shipbuilding and Engineering Company, does not appear to compare with that in the Auris on fuel consumption and thermal efficiency. Apart from the straight gas turbine, a form of propulsion which is showing great promise is the free-piston gas generator. Several French vessels, including minesweepers and a coastal vessel of 850 tons, are equipped with gas generators which gave very satisfactory results in 1954. In the United Kingdom, Smith's Dock Company and Chas. D. Holmes and Company, have taken up licences for free-piston gas generators and are working on their development. In the United States, development work is also being undertaken; the research programme for increasing the speed of Liberty vessels includes the installation of gas generators.

Parallel with the development of new forms of propulsion, a steady improvement in the design of Diesel engines and steam turbines has been taking place. The urgent need to cut operating costs and increase earnings calls for small engine rooms and more cargo space, higher-powered engines but lower running costs. The supercharged engine of modern design (giving 30 per cent. more power) and operating on boiler oil, is proving to be an admirable answer to the problem.

NAVY FOR ATOMIC WAR

The Navy's modest construction programme for 1955–56 comprises mainly the modernising of destroyers, the conversion of destroyers to frigates, and the construction of new anti-submarine frigates and more coastal minesweepers. In the United States, where the aircraft carrier Forrestal of 60,000 tons (and costing 218 million dols.) was launched in 1954, at least two other vessels of this type are at present being built, and the large naval programme includes 7 more. In the United Kingdom the new Ark Royal (costing £21·5 million) has been commissioned, and as Mr. J. P. L. Thomas, first Lord of the Admiralty, has pointed out in an explanatory statement on the Naval Estimates, the fleet will soon contain a strong force of new or modernised carriers. This statement on naval policy, perhaps the most important made since the war, lays down that the carrier will be the core of the fighting fleet. Its aircraft will be able to deliver the atomic bomb. It will be given medium-range protection by a cruiser relying on an armament of guided missiles. These at first will be ship-to-air, but later a ship-to-ship weapon will be developed from the same equipment. "The guided weapon ship," according to the statement, "is revolutionary and will, we believe, effect changes in certain types of naval warfare comparable to that once brought about by the introduction of the Dreadnought." The present British cruiser fleet is old, and until the guided missile ships can be built, three Tiger Class Cruisers with modern gun armaments are to be completed and the best of the cruisers in commission will be modernised.

Both technically and economically the outlook for shipbuilding is very promising. The reduction of order books to manageable proportions is no bad thing now that there seems to be every prospect of a reasonable continuity of work. Full order books and inability to give delivery have been responsible for the loss of many valuable orders to foreign competitors. It is particularly unfortunate that the Norwegians, who have hitherto been the best British customers, and who ordered about 40 dry-cargo vessels valued at about £30 million during 1954, placed no contracts in the United Kingdom. With the levelling-up of British and foreign order books, British shipbuilders are assured of their share in orders. Buoyant freight rates have at last resulted in a demand for new dry-cargo vessels to replace the large volume of over-age tonnage still at sea. In a period of rapid technical development, British shipbuilders have the means and ability of providing the British mercantile marine with the efficient ships so urgently required.

* * *

PREVENTION OF SCALE AND CORROSION

Methods Applicable to Water-cooled Internal-combustion Engines

In a paper presented to the Diesel Engine Users Association, on February 17, entitled "Prevention of Scale and Corrosion in the Water Cooling Systems of Internal-combustion Engines," Mr. E. L. Streatfield, B.Sc., F.R.I.C., M.I.Chem.E.,* dealt with both causes and cures. After describing typical cooling systems, he mentioned the various types of water encountered and described the effects of the impurities they contained.

Dealing in the first place with scale, Mr. Streatfield described three main softening processes frequently employed in treating make-up water. The first of these, the lime-soda process, removes both temporary and permanent hardness, and is very effective if carried out hot. It does not effect either sodium sulphate or sodium chloride, but it does given an overall reduction in dissolved salts of about 20 to 25 per cent. The second process mentioned, the base exchange or zeolite process, removes hardness and requires less space for plant. On the other hand, it does not reduce the amount of dissolved salts and may increase corrosion due to the presence of sodium bicarbonate, which decomposes on heating to produce dissolved carbon dioxide.

The third process described by Mr. Streatfield was de-ionisation. This process gives water almost as pure as if distilled, but it cannot be economically applied to the treatment of sea water. The water to be treated is passed over beds of cation and anion exchange materials which remove all ionisable salts. The materials normally employed are either carbonaceous geolites or synthetic resins, based on phenol-formaldehyde and sulphonic acid for cation removal and synthetic resins based on aromatic or aliphatic amines to remove anions. Any dissolved carbon dioxide can be removed by de-gassing and any silica by passing the water over a bed of strongly basic anion exchange resins.

The author added that in cases where water treatment was not carried out before entry into the cooling system, the addition of organic colloids, such as certain tannins, could be made to the system itself. Organic sequestering agents such as ethylene-diamine-tetra-acetic acid could also be used.

Mr. Streatfield then proceeded to outline the current ideas on the mechanisms of corrosion, by oxygen attack or electrolytic action. Inhibitions he divided into three broad classes, anodic, cathodic and organic. The first group included such alkaline compounds as phosphates, silicates and carbonates, which are much used in steel cooling systems. It must be remembered, however, that if added to water containing calcium bicarbonate, the first reaction would be to precipitate calcium carbonate, thereby softening the water but using up the inhibitor, Large amounts would therefore have to be employed. Other anodic inhibitors were chromates and nitrites, which do not require the presence of dissolved oxygen. He warned that both alkaline and oxidising inhibitors must be used in sufficient quantity when added to water containing chloride, or they would merely serve to intensify the attack.

The best known of the cathodic inhibitors, said Mr. Streatfield, was calcium bicarbonate, already present in hard waters. On its own, however, it was a rather inefficient inhibitor, but was improved by the presence of condensed phosphates.

In the organic group (the action of which was probably anodic), Mr. Streatfield mentioned particularly, certain blended tannins and also sodium benzoate. The tannins absorb oxygen and form protective film on the surfaces and have the additional advantage of preventing the formation of scale. They are equally effective when used in ethylene glycol solutions used for anti-freeze purposes. Sodium benzoate can also be used in anti-freeze solutions in which it prevents corrosion between two dissimilar metals in contact. Alone, it is effective with mild steel and soldered joints and with the addition of sodium nitrite, will protect cast iron as well. The corrosion of lead, copper and aluminium alloys exposed to attack by glycol solutions, has been largely prevented by the use of other organic agents, namely, triethanolamine phosphate, and sodium mercaptobenzthiazole. Mr. Streatfield illustrated the paper with examples of cylinder blocks and liners in which corrosion had taken place and where inhibitors had been used.

* Director of Research, Houseman and Thompson Limited, Newcastle-upon-Tyne.

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LABORATORY-MADE DIAMONDS

Extra-high Hydraulic Pressures

A critical inspection and test appears to have substantiated the claim, made by an American firm, to have produced the first diamonds ever made in a laboratory. They were made by subjecting carbonaceous material to a temperature of more than 5,000 deg. F. and a pressure of over a million lb. per square inch. This pressure was obtained and controlled by pumps and control valves applied to a powerful hydraulic press. The pumps used were standard Electraulic axial plunger pumps working at 5,000 lb. per square inch, made by Towler Brothers (Patents), Limited, Rodley, near Leeds. The pressure from the pumps was intensified by means of a multiple-ram system. Extremely accurate control of pressure was needed to produce the diamonds, and it was proved in tests before despatch to America that a specially-designed Electraulic variable-pressure relief and unloading valve would maintain a pumped pressure of 5,000 lb. per square inch for several days with a variation of only ± 0·1 per cent. of the maximum pressure. The valve is adjustable, and will maintain a given pressure without material variation for long periods.

ELECTRICAL ENGINEERS EXHIBITION

TRADE DISPLAY OF DOMESTIC AND INDUSTRIAL GOODS

This year's Electrical Engineers Exhibition, which will be held at Earls Court, London, S.W.5, from March 15 to 19, shows another large increase in size in comparison with previous years. There are 242 exhibitors (as against 179 last year) and the floor area is increased by a half to 250,000 square feet. The exhibition, which is open to the trade only, will be formally inaugurated by the Rt. Hon. Lord Citrine at noon on March 15.

Since motors form the special feature this year, a large variety of these machines is to be shown. Lancashire Dynamo and Crypto, Limited, St. Stephen's House, Victoria-embankment, London, S.W.1, are showing for the first time their range of motors to Anglo-American standards that was announced recently. These include both protected and totally-enclosed types. Another new model to be exhibited is a 2,000 h.p., 2,980 r.p.m. Silentvent motor which has been developed for such high speed drives as boiler-feed pumps where windage noises created by the ventilated type have caused inconvenience. A " Corcooled " flameproof motor with sleeve bearings and flameproof glands of a new design is also to be shown.

The latest addition to the " N " range of motors made by Crompton Parkinson, Limited, Aldwych, London, W.C.2, is the type NK, examples of which will be exhibited. One of them is illustrated in Fig. 1. They are totally-enclosed fan-cooled induction motors ranging from 80 to 600 h.p., and models are available with different starting characteristics. By fitting different rotors, the squirrel-cage machines can be supplied for three starting conditions. A double air-cooling system is fitted for the totally enclosed parts, one stream circulating through the rotor core and behind the stator laminations, and the other through ducts in the stator cores. This firm will also be showing motors to international standards, the range having been developed for domestic appliances.

One of the exhibits in the " Motor Way " avenue will be a vertical hollow-shaft pump motor made by Newman Industries, Limited, Yate, Bristol. This is the prototype of a range extending from 1½ to 125 h.p., and including both hollow and solid shaft types. They are squirrel-cage induction motors, designed primarily for deep well turbine pump applications, and conform to NEMA standards, both dimensionally and electrically. Other features are very heavy thrust bearings and an optional non-reverse ratchet to protect the pump from damage due to accidental reversal of the motor or " backspin " caused by the water draining back through the pump. Both totally-enclosed and drip-proof models are made. A wide range of other motors will be shown on the firm's stand.

Accurate dynamic balancing of rotors is an important item in the manufacture of high-speed motors. Last September we described two machines for this purpose (ENGINEERING, vol. 178, page 345, 1954). Now the same firm, E.M.I. Electronics, Limited, Hayes, Middlesex, will be displaying three console models for this operation, having a wider capacity. One of them is shown in Fig. 2. The weights of the workpieces that can be accommodated by each model are: 4 oz. to 5 lb.; 1 lb. to 30 lb.; and 10 lb. to 150 lb. The two smaller machines have a capacity between bearing centres of 15 in. and will accept work up to 15 in. in diameter, while these figures are both increased to 24 in. for the largest size. It is claimed that displacements as small as 0·000025 in. produced by out-of-balance forces can be detected. As in the earlier models, the amount of the out-of-balance force is indicated by a meter and the position by a stroboscopic lamp. For high speed testing, as when installed in a production line, the machines can be fitted with automatic braking, and also an automatic pneumatic belt-lift for workpieces not exceeding 4 in. in diameter. The largest size is driven by a ½-h.p. motor, the others by ¼-h.p. motors; all three are made to tropical specification.

On the stand of Johnson and Phillips, Limited, Charlton, London, S.E.7, typical examples of their range of switchgear, transformers, capacitors and cables will be shown. Switchgear will include models up to 250 MVA at 11 kV, as well as such items as pole-mounting fuse-switches and industrial types. A 333-kVAr capacitor will also be shown. The centre piece of the stand, however, will be two transformers to demonstrate the relative size using different steels for the laminations. One is rated at 100 kVA and is made with hot-rolled steel laminations, while the other, smaller in size and lighter in weight, is rated at 150 kVA but has cold-rolled laminations. This is possible because losses in cold-rolled steel are at least 15 per cent. less than in hot rolled; consequently a higher flux density can be used with a corresponding saving in size and weight.

A large variety of relays will be exhibited by Londex, Limited, 207 Anerley-road, London, S.E.20. Among them will be a smoke density alarm for industrial applications. The alarm has been mounted in a model chimney and has a delayed action so that the warning is not given for occasional puffs of smoke. It is expected that this type of instrument will be required for chimneys in future smokeless zones as considered in the recent Government report. This relay can be set to operate at a particular smoke density. Also on the stand will be a calibrated sensitive relay, illustrated in Fig. 3, which is adjustable over a wide range of operating currents; and several process timers. The most recent of these is a flush-mounting model designed to match control board instruments and it is available with timing ranges varying from 10 seconds (calibrated in 0·1 sec.) to 72 hours (calibrated in hours). The timer is driven by a synchronous motor, of 2 VA consumption, and can be adapted for all usual switching operations.

Induction-heating units are to be represented on the stand of Radio Heaters Limited, by the 6-kW Radyne forge and a melting furnace. The forge is illustrated in Fig. 4. It is provided with a wide range of control which allows a variety of heating coils to be used. It is intended mainly for soldering and brazing, but other processes involving heating can be carried out on it. One of the main claims is that it is sufficiently versatile for general workshop use. The melting furnace utilises the 6-kW heating unit and has a lip-pouring melting pot with a nominal capacity of 5 lb., mounted on the front. The time for melting 5 lb. of steel is given as 25 minutes.

The Record Electrical Company, Limited, Altrincham, Cheshire, are showing examples of their Cirscale meters and graphic recorders. A new introduction among the latter is a portable

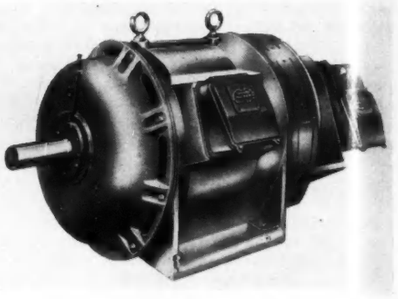

Fig. 1 Totally-enclosed fan-cooled motor with a double air circulation system.

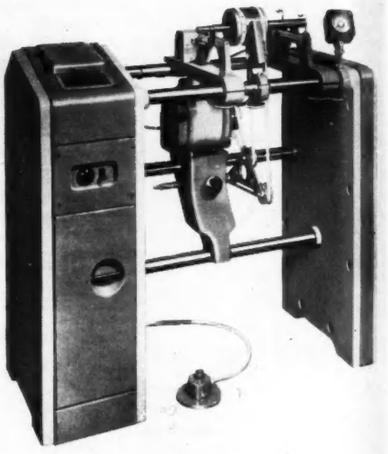

Fig. 2 Three models of this type of dynamic balancing machine cover workpieces ranging in weight from 4 oz. to 150 lb. Displacements of 0·000025 in. can be detected.

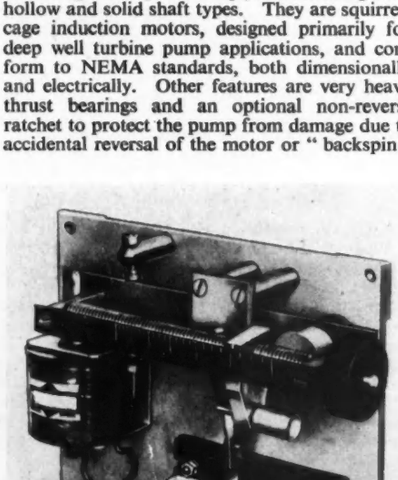

Fig. 3 Calibrated sensitive relay with a wide range of adjustment.

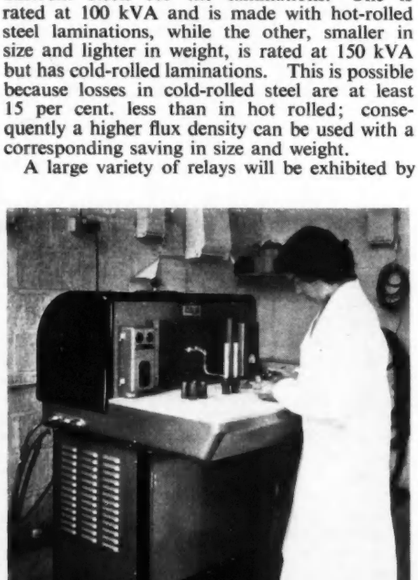

Fig. 4 Many types of heating coil can be used with this 6-kW induction heater. It can be fitted with a 5-lb. melting pot.

instrument which utilises a clip-on transformer for its supply. This enables records to be made of current in existing lines without the difficulties of time and labour involved in breaking the line and connecting the recorder in series. In order to give accurate records, the movement is of the rectifier moving-coil pattern, with a full-scale deflection given by 1 milliampere. A thumb-operated selector switch gives a choice of seven ranges—6, 15, 30, 60, 150, 300 or 600 amperes. The clip will surround cables up to 2¼ in. in diameter, and the case is insulated to 600 volts. The recorder itself is of a standard pattern, normally driven by an eight-day clock-work mechanism, but a synchronous motor can be fitted if desired. Standard chart speeds are 1 in. or 6 in. per hour. It is possible to use the recorder separately from the clip-on transformer, and for this it has three voltage ranges—150, 300 or 600 volts—built into it. These ranges have a resistance of 1,000 ohms per volt.

THE POST-WAR ELECTRICAL ENGINEERING INDUSTRY

PROBLEMS OF PRODUCTION, RESEARCH AND EXPORT

By G. L. E. Metz

Since 1946, almost every Presidential Address to the Institution of Electrical Engineers has stressed the fact that we live in an age of specialisation; and the importance of stopping occasionally to see where we are going and what we are achieving. Sir Henry Tizard has suggested that the underlying feelings of disquiet in these pronouncements is due to the fact that the strategy of industry has gone wrong, as a result of failure to keep its objectives in view; and that consequently the resources at its disposal have not been effectively utilised.

ECONOMIC BACKGROUND

Since the war, new patterns of industrial activity are being woven and the under-developed countries are on the march towards higher standards of living and the development of their own resources of material and labour. Unfortunately this progress has not been accompanied by greater understanding, but on many sides by the desire to close the doors to the exchange of ideas and merchandise. This trend is bound to create problems for us, because our prosperity depends upon our ability to convert imported raw materials into finished goods which other people want. For some years we have imported more than we have exported; and if the present standard of living is to be maintained there must be a rapid increase in production and in the efficiency with which we use the resources at our disposal. The driving force for this expansion can only come from industry. This has a special importance for the engineering and metal-using industries because together they account for nearly 44 per cent. of all exports. Furthermore, the electrical industry, together with electricity supply, is one of the keys to greater and more efficient production in other exporting industries.

INDUSTRY CAN DO MORE

Progress in production, exports and employment during the last few years gives good cause for satisfaction. Nevertheless, it is necessary to consider whether the electrical manufacturing industry cannot do more to help other industries to increase production and exports. This is a difficult problem, the solution of which depends largely upon increasing productivity; that is the production per employee. As it is, production per man-year in the electrical industry has only reached a modest figure for an industry in which there has been considerable capital investment and which includes some of the most efficient plants in the world. In fact, the great advances in the application of more effective techniques, which have taken place, have been used to provide easier conditions for employees and to reduce the number of working hours. The question therefore is not why we do not produce more, but why we do not want to produce more.

PSYCHOLOGICAL FACTORS

Productivity cannot be increased merely by the addition of capital equipment and power. While wonderful advances in scientific and technical knowledge have been taking place the application of it to worthy causes has hardly advanced at all. As a result the knowledge so laboriously gained cannot be fully translated into action because the wisdom which alone can provide a source of direction is lagging behind. It almost seems that while we have arrived at a point where technical knowledge could provide so many of the things we all desire, the power to provide them still lies outside our grasp, because the will to turn these possibilities into reality is lacking. But whether people want more goods or more leisure they can only get them by increased and more efficient production.

Since the war the demand for electrical plant, equipment and appliances has far exceeded the capacity for producing it. There are signs, however, that production is now overtaking demand; and it seems inevitable that our share of international trade will fall unless we can find some means of combating the competition we shall encounter from Germany and Japan. Production therefore means something different from making two articles where one was made before or of making them more cheaply. There are certain vital balances which determine the optimum levels of trade, production and price, which deserve more attention than they have so far received.

RESEARCH AND DEVELOPMENT

It is easy to conclude from figures that the the United Kingdom spends too little on research. Capital investment which is necessary to turn the results of research to practical use has, until recently, however, been restricted by Government controls and is still limited by taxation, high cost of capital and the effects of inflation. It has consequently been necessary to consider whether to reduce the expenditure on research or to continue it and pigeon-hole the results.

At present more money is being spent by the electrical industry on research on heavy engineering than on light. This does not mean that research on improving the efficiency of turbo-alternators is a waste of time, but it is doubtful whether it will result in an increase in the demand for electricity. This raises the question whether the most fruitful field for research at a time when there is insufficient money to do all we should like to do is not in the design of improved industrial and domestic appliances. For this reason it would be of considerable assistance if there could be periodic reviews of the advances made and some attempt to signpost the possible fields of application.

The greater part of the United Kingdom export trade is with the members of the Commonwealth within the sterling group and the balance between imports and exports is better than in other sectors. The greatest unbalance occurs in the dollar account and non-sterling sectors in which it is most important for imports and exports to balance. The proportion of total cost represented by imported raw materials varies with the type of equipment. In the case of copper cables with cotton covering and rubber sheathing it is one half. Although this is an extreme case it shows that electrical exports do not contribute as much to the balance of payments as figures might suggest. It follows that one of the most effective ways of dealing with this problem is to eliminate the waste of all imported materials.

The pattern of overseas trade in electrical goods and appliances is not satisfactory. It is essential at present to maintain a reasonable balance between imports and exports with each of the sectors of trade. This means that we must increase our trade with the non-sterling sectors, and this entails breaking new ground so far as the electrical industry is concerned. If the electrical industry is to find a large and increased outlet for its exports it will have to look to European and other markets which together account for over half the world trade in electrical goods.

CONCLUSIONS

If Great Britain is to remain great she has first to rebuild her economic strength. This task has special significance for the electrical manufacturing industry because this industry holds one of the keys to increased productivity. There are other factors peculiar to the industry which affect the situation. The next few years seem likely to bring significant changes in the source from which energy for use in industry and the home is derived. There are, however, no signs of any medium better than electricity for the distribution of energy or for its ultimate application at the working level. Consequently, that part of the industry concerned with the distribution of electricity and its application seems unlikely to encounter the revolutionary changes that may affect the production of generating plant. Moreover, the field in which electrical labour-saving devices can be economically applied will widen as it becomes cheaper to hire plant than to hire labour. Factories also can now be run automatically. This will result in large savings in human effort and raise the problem of finding something else for the displaced labour to do. Further, the day is fast approaching when the fight for markets will be as intense as it was before 1938, so that it will be necessary to make our productivity higher than in the countries with which we have to compete.

To increase our productivity there must be a greater willingness to use new methods and labour-saving devices and a determination to act as a team rather than as isolated groups of individuals, not wholly sympathetic one with another. Engineers must explain the advantages offered by new machines and processes to those who have to buy and use them. The means for increasing productivity are available and there is an objective which is worth working for. This objective has, however, become obscured. It is a mistake to assume that the repository of all knowledge lies in the United States. If she has learned how to increase productivity we have learnt how to make many things better and cheaper. In particular, we are entitled to be very proud of the fact that British transformers and hydro-electric equipment have recently compared with the best America can produce and are now being installed there. There seems no reason why productivity in this country cannot be increased to the level reached in the United States.

The electrical manufacturing industry would seem to have a future which dwarfs even the spectacular advances of the last 20 years. But it also has responsibilities which, owing to the accidents of history, are in many ways greater than it has had to face before.

* Paper entitled "The Electrical Engineering Industry in the Post-War Economy" read before the Institution of Electrical Engineers on Thursday, March 3. Abridged.

STRESS CONCENTRATIONS

EFFECT OF STRESS GRADIENT ON CRACK PROPAGATION

As a result of the investigations on the Comet air liner catastrophes, the attention of the aircraft industry has been drawn forcibly to the necessity for paying more attention to the distribution of stress around stress raisers than has hitherto been mandatory. The lecture given recently before the Royal Aeronautical Society on "Some Problems Associated with Stress Concentration," by Mr. H. L. Cox, head of the engineering physics section of the National Physical Laboratory, was therefore aptly timed. In this lecture Mr. Cox showed how stress analysis was confirmed by static and fatigue tests, discussed some theoretical two-dimensional investigations, and considered some aspects of crack propagation.

Firstly, Mr. Cox illustrated the difference between a stress concentration, which arose simply because the stress lines had to flow round the obstacle, and a load concentration, such as a rivet transmitting a load to a plate, in which the stress lines had in effect to flow into the hole. A high intensification of stress near the point of application of the load was inevitable, whereas pure stress-concentration effects could often be avoided.

The lecturer then showed slides of crane hooks, eye bolts, chain links, springs, etc., which had broken under repeated loading at the points of maximum stress as indicated by computations of the stress distribution. Moreover, failure usually occurred at about the expected endurance for the computed stress ranges. In chain links, however, fatigue cracks never occurred at the inside of the crown although the stress range there was higher than at the outside or at the inside at the end of the straight side; this was, presumably, because the mean stress was compressive.

Commenting on a slide showing fatigue cracks in a rectangular-section spring, Mr. Cox observed that, whereas these had propagated on planes of maximum shear stress, the cracks observed in lifting gear had propagated on planes of maximum tensile stress. The cracks on the spring had advanced only slowly into regions originally subjected to lower stresses.

Recent evidence had shown that the rate of propagation of cracks starting in regions of high stress depended greatly on the rate at which the stress fell off. This point was illustrated by a slide which showed a crack at a fillet in a wide thin plate, where the stress concentration was only about 1·2 but the stress gradient was not very steep. In the same plate no cracking occurred at a hole where the stress factor was 3 but the gradient was much steeper.

The lecturer then discussed the results of two-dimensional mathematical investigations on a variety of holes and grooves in an infinite plate, from which he drew the conclusion that, under direct stress, the stress concentration factor for an elliptical hole afforded a remarkably good approximation to the factors for a wide range of holes and grooves, and that abrupt changes of curvature in themselves did not affect stress concentration. Under shear the approximation was less accurate.

By analysis of the stress concentration due to a small crack or flaw at the root of a notch, and comparison with the concentration due to the same flaw in a plain test-piece, Mr. Cox had demonstrated that the effective stress-concentration factor due to a notch in a flawed material would be insensitive to notch root radius. This conclusion was in line with the results of tests on a number of steels containing sharp V-notches, but it could not be accepted as the explanation of these results because the size of the flaws required would be appreciable in comparison with the depth of the notch, and therefore these flaws should have been observable. There were other serious objections to the hypothesis.

In tests on round mild-steel bars with circumferential V-notches under tension across the notch, it was found that the ratio of the average shear stress in the notched section to the tensile load also depended mainly on the depth of the notch and only to a small degree on the root radius. This observation was confirmed by complete analyses of two notch forms by the photo-elastic frozen-stress method.

In conclusion, Mr. Cox showed slides illustrating the varied behaviour of cracks propagating under repeated loading, and suggested that a better understanding of the problem might result if more attention were paid to the stress distribution round the advancing crack.

* * *

HIGH VOLTAGE TRANSMISSION IN SWEDEN

Direct and Alternating Current Developments

During a lecture on "High Voltage Developments in Sweden," which he delivered before the Supply Section of the Institution of Electrical Engineers on Wednesday, February 23, Mr. Abe Rusck, president of the State Power Board, gave some details of the high-voltage direct-current system between the Island of Gotland and the main land*. He said that the first months of operation had been quite successful and the result of the research and development work on which the project was based had been confirmed. In fact, the problem of high-voltage direct-current transmission had been solved.

Mr. Rusck showed a film illustrating the production of an ionic-valve converter, the erection of the converter stations, the manufacture of the cable and its laying by the British Post Office cable ship Alert. From the beginning of the loading of the cable to the clearing of the ship for its return voyage 16 days elapsed. From April 12, 1954, to the last week in July, power up to 10 MW was transmitted in both directions, this being the rated load of the converter. On July 26 a second set was started and the transmission capacity was increased to 20 MW with a possible overload of 25 MW. It was easy to change over from one direction of supply to the other, but most of the time power had been transmitted from the mainland to Gotland.

OPERATING EXPERIENCES

There had been two cable faults, neither of which was very serious. The first was probably caused during manufacture or laying; and the second occurred when a ship dropped anchor on the cable close to the mainland. The converters, which were the most difficult part of the equipment, had behaved extremely well. There had been no commutation failures which was reassuring. In October, a series of short-circuit tests were carried out on the alternating-current side of the inverter station. A total of 30 shots were made at different distances from the station, ten of them being directly on the alternating-current terminals. The resulting oscillograms showed that the inverters were capable of operating normal during short-circuit.

Dealing with the future, Mr. Rusck said that had present-day knowledge been available seven years ago, a higher voltage, probably 450 kV, might well have been chosen for alternating-current transmission. The insulation of the present 380-kV lines was on the conservative side and would allow a voltage of 500 kV to be used when internal voltages had been reduced.

* Engineering, vol. 177, page 715 (1954).

In order to avoid radio interference it would be necessary to add a third conductor in each phase. The present transformers would have to be re-wound or provided with boosters. It was not out of the question that the voltage of the present system would be increased to 500 kV at least in some parts of the system.

650 kV TRANSMISSION POSSIBLE

A new system operating at about 650 kV and using four bundled conductors was also being investigated. Such a line would have a transmission capacity of about 2,000 MW with series capacitor compensation. Another possibility would be to use extra high voltage direct-current. Work was proceeding to provide ionic valves for a higher voltage and larger capacity than those used on the Gotland scheme and the prospects seemed favourable. Calculations were now being made on a direct-current system for $\pm$ 400 kV. This would have about the same transmission capacity as the 650-kV alternating-current line. Alternating and direct-current transmission both had their special advantages and a final solution would need a great deal of technical and economic comparisons.

In conclusion, Mr. Rusck said, "To-day I am not sure that we really need a 'super-super' system. Our potential hydro resources in the northern part of the country have been recalculated and the figure is about twice as high as when we decided to choose the 380-kV voltage. On the other hand, the transmitting capacity of a 380-kV voltage line has been increased by using series capacitors. Further, the load increases in the northern districts, and in 10 to 20 years nuclear power plants may take care of some of the load in the southern regions."

* * *

WATER SUPPLY CONGRESS AND EXHIBITION

London, July, 1955

The third congress of the International Water Supply Association is to be held in the halls of the Royal Horticultural Society, Westminster, London, S.W.1, during the week commencing July 18, 1955. Previous congresses were held in Amsterdam in 1949 and Paris in 1952, but this will be the first occasion on which there will have been an exhibition of waterworks equipment and services. Representatives from 29 countries have attended the two previous congresses and over 1,000 delegates are expected to attend the London meeting.

In all, nine papers are to be presented by general rapporteurs, as follow :

(1) "Protection of Pipelines against Water Hammer," Mr. C. Dubin (France).

(2) "Pumping Station Equipment," Mr. Hugh R. Lupton, O.B.E., M.C. (Great Britain).

(3) "Design and Construction of Service Reservoirs and Water Towers," by Mr. Hilding Bjorklund (Sweden).

(4) "Aeration and Deferrisation," Dr. L. H. Louwe Kooijmans (Netherlands).

(5) "Factors of Safety in Supply and Delivery Systems (catchment, main feeders, reservoirs, networks, etc.)," Mr. A. Vibert (France).

(6) "Use of Electronic Apparatus in Waterworks Practice with Special Reference to Waste Detection," Mr. R. E. A. Despiegelaere (Belgium).

(7) "Comparison Between Slow Sand and Rapid Filters," Dr. A. Van de Vloed (Belgium).

(8) "Training of Waterworks Operators," Mr. H. R. Davenport (Great Britain).

(9) "Methods of Charging for Water," Mr. E. Sherman Chase (United States of America).

In conjunction with the congress, arrangements have been made for visits to places and works of professional interest. A full programme of social functions, including an official banquet and excursions for ladies who accompany the delegates, will also be arranged. Full details and forms of application may be obtained from the secretary-general, International Water Supply Association, 34 Park-street, London, W.1.

THE ENERGY THEOREMS OF STRUCTURAL ANALYSIS

1—DEFINITIONS AND FUNDAMENTALS

By E. H. Brown, PH.D., B.SC.(ENG.), D.I.C.*

The conservation of energy appears to be a habit of Nature. It has a wide generality, and is the basis of diverse scientific theories. But it is not sufficient of itself to solve problems in structural analysis; it does not imply equilibrium, nor the compatibility of displacements and strains, nor any specific force/displacement relations, and these are the three principles on which elastic structural theory rests. In conjunction with one or more of the principles, however, it admits several theorems which are both powerful and convenient in the solution of engineering problems.

This article has three objectives: to set out the various theorems of strain energy and complementary energy, with their physical meanings, conditions and limitations, considering structures with either linear or non-linear load/displacement curves; to illustrate the theorems and discuss their use and the relations between them; and to present a new examination of complementary energy and its application. The theorems are not, of course, new (although no one reference gives them all), but in one or two cases their limitations have not, to the author's knowledge, been precisely stated before. Many of the approaches given here are believed to be original, and make for clarity and new perspectives from which the theorems and the relations between them will be considered in the discussion at the end of Part 2 of the article

The first part of the article gives definitions and fundamentals, the second derives nine theorems and discusses them, the third contains a worked example to illustrate each theorem. Part 3 will demonstrate the mathematical contrast between the proofs, which establish conditions, and applications, which use only the results of the proofs.

NOTATION

The following notation has been adopted throughout the articles:—

r = one of the points of a structure at which loads are applied;
s = a particular one of the points r;
i = a point in a structure where a "cut" would release a redundant force; or any point of a structure other than the points r;
j = a particular one of the points i;
δ_r = displacement at r in a specified direction, zero when no external loads are on the structure;
Δ_r = value of δ_r when all loads have reached their ultimate values;
d_r = displacement at r in a specified direction, zero when no external loads are acting and a minimum number of cuts have been made in the structure so as to release all the self-straining;
D_r = value of d_r when all loads have reached their ultimate values and additional forces have been applied at the "cuts" to close the gaps;
P_r = external force applied at r;
Q_i = internal redundant force, moment or stress at i;
R_r = reaction of the structure at r;
$\sigma_x, \sigma_y, \sigma_z$ = direct stresses;
$\tau_{xy}, \tau_{yz}, \tau_{zx}$ = shear stresses;
$\epsilon_x, \epsilon_y, \epsilon_z$ = direct strains;
$\gamma_{xy}, \gamma_{yz}, \gamma_{zx}$ = shear strains;
S = complementary energy;
S_o = complementary energy of self-straining;
T = kinetic energy;
T_n = internal force at point n;
U = strain energy;
U_o = strain energy of self-straining;
V = potential energy of external forces;
V_o = arbitrary datum level of V;
$\gamma = \dfrac{\delta_r}{\Delta_r}$, when all the loads are being slowly built up together in such a way as to make γ the same for all values of r. $(0 < \gamma < 1)$;
λ_i = initial lack of fit at i; i.e., the dislocation at i if a minimum number of cuts (including one at i) are made in the structure so as to release all the self-straining;
e_n = internal extension corresponding to T_n;
k = stiffness coefficient (linear structures only), such that $\delta = kP$, or $e_n = k\,T_n$;
$R_r(\delta_r)$ = the value of R_r corresponding to a displacement δ_r, implying that, in general, R_r varies if δ_r varies; $R_r(\Delta_r)$ is then the value of R_r when $\delta_r = \Delta_r$.

Functional forms, such as $R_s(\delta_s, \Delta_r, \Delta_s, \Delta_t)$ for example, will often be used as a reminder that R_s varies if any of the quantities δ_s, Δ_r, etc., vary.

Only structures which are elastic will be discussed; that is, structures in which deformation disappears when the loads causing it are removed. Structures with either linear or non-linear load/displacement characteristics will be considered, and where allowance for non-linear systems leads to complicated expressions the simplifications possible with linear systems will be given also.

FORCES AND DISPLACEMENTS

Throughout the article we shall refer to external forces P_r, and displacements Δ_r, in the same direction as the corresponding forces. Sometimes a problem may involve two or three mutually perpendicular force components acting at one particular point; they may be considered as independent external forces, the appropriate displacements being the corresponding deflection components.

In all cases the results are valid if P_r represents a moment instead of a force, and Δ_r the angle through which the moment rotates.

SUPPORTS

A structure subjected to any number of external loads and moments can always be held in equilibrium by an appropriate number of statically-determinate supports, provided the loads are not so great as to cause a structural failure. The point of application of such a support has no motion in the direction of the support during any variations of the loads, giving a fixed frame of reference for measuring displacements and ensuring that the supports, which may be varying in magnitude, do no work. The term "displacement" therefore will always denote a movement relative to the points of application of the statically-determinate supports.

When the supports to a structure do yield elastically under load they may be replaced in the analysis by fictitious "springs" with appropriate load/displacement characteristics. The springs (which will store energy) are then incorporated into the structure, and are themselves resting on unyielding supports.

If the structure has additional, redundant, supports they are to be considered as unknown external forces, whose values may be found from the condition of zero displacement at their points of application.

POTENTIAL ENERGY OF FORCES

Initially, any force applied to a structure has a capacity to do work. This capacity is termed the potential energy of the force, is measured from an arbitrary datum, and is called V_o.

If the force is constant and does work, its potential energy is reduced to $V = V_o - P\Delta$; if, on the contrary, the magnitude of the force is a function of its position (for instance the force applied to a structure by the end of a compressed spring) the potential energy after working becomes

$$V = V_o - \int_0^{\Delta} P(\delta)\,d\delta$$

which is V_o less the area under A-B in Fig. 1. In the event of P varying with δ, however, it is to be remembered that the variation depends upon the field of force (for example, in the case mentioned above it depends upon the stiffness of the spring), and *not* upon the elastic properties of the structure to which P is applied.

STRAIN ENERGY

The strain energy stored in an element $dx\,dy\,dz$ of an elastic body is defined as the recoverable work done in straining it. Denoting the direct and shear stresses by $\sigma_x \ldots$, $\tau_{xy} \ldots$, and the corresponding strains by $\epsilon_x \ldots$, $\gamma_{xy} \ldots$, the work done on the element is made up of such terms as

$$\int (\sigma_x\,dy\,dz.\,dx\,d\epsilon_x)$$

where the integration is with respect to $d\epsilon_x$. Then the strain energy of the element is

$$dU = dx\,dy\,dz \int (\sigma_x\,d\epsilon_x + \sigma_y\,d\epsilon_y + \sigma_z\,d\epsilon_z + \tau_{xy}\,d\gamma_{xy} + \tau_{yz}\,d\gamma_{yz} + \tau_{zx}\,d\gamma_{zx}). \quad (1)$$

If the stress/strain law is linear, then

$$dU = \tfrac{1}{2}\,dx\,dy\,dz\,\{\sigma_x\,\epsilon_x + \sigma_y\,\epsilon_y + \sigma_z\,\epsilon_z + \tau_{xy}\,\gamma_{xy} + \tau_{yz}\,\gamma_{yz} + \tau_{zx}\,\gamma_{zx}\}. \quad (1a)$$

The total strain energy, U, is found by integrating this expression throughout the volume of the body. It is shown in Appendix I (page 307) that U is independent of the way in which the strains attain their ultimate values.

As an example, consider the bending energy of an elastic beam obeying Hooke's Law, and neglect the energy due to shear. By assuming that cross-sections initially plane remain plane after bending we have, in familiar notation, $\sigma_x = E\epsilon_x = My/I$, where M and I are functions of x only. All other stresses are taken to be zero.

Then

$$\int_0^{\epsilon_x} \sigma_x\,d\epsilon_x = \frac{E\epsilon_x^2}{2} = \frac{M^2 y^2}{2\,EI^2}$$

so that

$$U = \int \left\{ \frac{M^2}{2\,EI^2} \iint y^2\,dy\,dz \right\} dx;$$

and since by definition the second moment of area $I = \iint y^2\,dy\,dz$, we have the well-known formula

$$U = \int \frac{M^2\,dx}{2\,EI}.$$

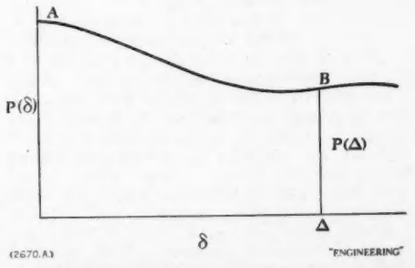

Fig. 1 The potential energy of a force applied to a structure is reduced by the amount of work that is done by the force, represented by the area below the curve AB.

* Civil Engineering Department, Imperial College of Science and Technology.

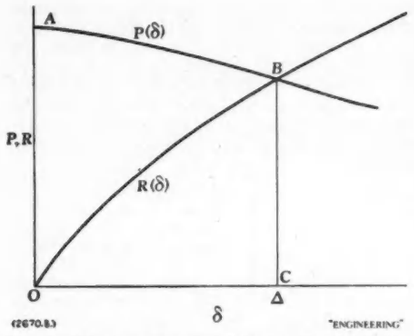

Fig. 2 The intersection of the load and reaction curves gives the equilibrium displacement. The loss of potential energy is given by the area OABC; the increase in strain energy by OBC.

SELF-STRAINING

The strain energy of an elastic structure is not necessarily all given up when all the external loads are removed. Because of non-uniform temperature effects, or of force used in its initial assembly, an unloaded structure may be storing strain energy which can only be released by cutting the structure. As an example, consider a simple framed structure into which an additional (redundant) member, initially too short, is fitted by force; the resulting frame may be heavily stressed when no external loads are acting on it whatever. To this phenomenon, which can only occur in structures which are not statically-determinate, Southwell[1] has given the name "self-straining."

Consider a simply-supported ill-fitting elastic structure at its forced assembly, and let the gaps be held just closed by pairs of equal and opposite external forces. Let another load P be applied at some point r, together with equal and opposite increments to the original forces so as to keep the gaps closed. Then, *if the structure obeys Hooke's law relating load and displacement*, the principle of superposition asserts that Δ, the movement at r caused by these new forces, is independent of the original forces.

Had the structure been "cemented up" before P was applied the external loads at the gaps could have been removed, leaving a self-strained structure. The deformations would have been unaffected, and our previous argument now becomes that Δ is independent of the extent of self-straining. Thus the stiffness of the structure Δ/P, and the increase in strain energy $\frac{1}{2}P\Delta$, are both independent of the self-straining, which may therefore be ignored in calculation of the effects of P.

This is not true of structures not obeying Hooke's law. Their stiffnesses depend upon the amount of self-straining, which must be known before the effect of applied loads can be determined.

CONSERVATION OF ENERGY

When a constant force P is applied to an initially unloaded elastic structure at a point r the structure builds up a reaction R at r opposing the force, and the work done *on the structure* is given by the area under the reaction/displacement curve, for the reaction represents the part of the load actually taken by the structure at a particular displacement, increasing from zero to P as the displacement increases from zero to Δ. This distinction between the reaction and the applied load is important; we shall see that it explains the identity of certain well-known energy theorems with the concepts of equilibrium and stability, and it greatly simplifies discussion of the conservation of energy.

By the conservation principle, the area under the reaction/displacement curve given in Fig. 2 must give the increase of strain energy stored in the structure, so that

$$U = U_o + \int_0^{\Delta} R\,(\delta)\,d\delta$$

where U_o is the initial energy of self-straining, if any. R varies with δ according to the elastic properties of the structure. If P also varies with δ, a variation which will not depend upon the properties of the structure, equilibrium is possible at some displacement Δ where $R(\Delta) = P(\Delta)$. (See Fig. 2: note that no stipulation has been made of linear reaction/displacement characteristics; if it is a linear relation, so that $R(\delta) = k\delta$, U simplifies to $U_o + \frac{1}{2}k\Delta^2$, or $U_o + \frac{1}{2}\Delta.R(\Delta)$; if it is not a linear relation it will depend upon the extent of any initial self-straining.)

Whether or not P is constant it will always do more work during the displacement Δ than R will have done upon it, so that the loss of potential energy will be greater than the gain in strain energy; this is illustrated in Fig. 2. There is thus a fall in the sum of the potential and strain energies (sometimes called the "total potential energy" of the system) which is in apparent conflict with the conservation principle. It can be accounted for in one of two ways.

First, the force may be applied "slowly." That is, some *extraneous* reaction to the load can be supplied, decreasing from P to zero as the displacement grows from zero to Δ, in such a way that the sum of the extraneous reaction and $R(\delta)$ is always $P(\delta)$, and at such a rate that the kinetic energy during the movement is negligible. In this case the extraneous reaction has work done on it equal to the amount of the drop in the total potential energy, the area OAB in Fig. 2.

Alternatively, the force may be applied "suddenly"; the whole force $P_{(\delta=0)}$ comes on to the structure at time t_0. Since $R_{(\delta=0)} = 0$, static equilibrium is not maintained, and the force $P(\delta) - R(\delta)$ is devoted to producing accelerations in the structure. A kinetic energy T is thus created and absorbs the excess potential energy which is not converted into strain energy. The conservation of energy at any instant is now expressed by $U_o + V_o = T + U + V$. The kinetic energy continues to grow while there is an accelerating force, that is, while $P(\delta) > R(\delta)$; when $\delta > \Delta R\ (\delta) > P(\delta)$, there is a decelerating force, and the kinetic energy is gradually converted to strain energy until at some displacement δ_1 the increase in strain energy is equal to the loss of potential energy of the force, the kinetic energy is zero, and the structure is momentarily stationary. This process is depicted in Fig. 3. However, $R(\delta_1) > P(\delta_1)$, so there is still an accelerating force and the kinetic energy is built up again, with reversed velocities. The structure will thus vibrate and, in the absence of any damping, vibrate indefinitely.

SEVERAL APPLIED LOADS

The deformation of an elastic structure under a given system of loads is usually independent of the order in which the loads are applied, but in certain cases of large displacements this is not so, and the order of loading must be specified before the displacements and stresses can be determined.

On the other hand, corresponding to a given deformation of an elastic structure, there is a unique set of loads, irrespective of the way in which the deformation reaches its final configuration; for if the entire deformation is specified the strains are known, hence the stresses are known, and among them the boundary stresses, which must be balanced by the external loads. In Appendix I, it is shown that for a given deformation the strain energy is also independent of the way in which the displacements are built up.

If an elastic structure is to be deformed by loads at several points r (the loading order being specified if necessary, so that the deformation is definite), it is therefore fair to stipulate that all displacements δ_r be built up together and kept proportional to a single variable γ, increasing from zero to their final values Δ_r as γ increases from 0 to 1. Then $\delta_r = \gamma\Delta_r$. In this way there will be a definite reaction/displacement curve for each loaded point, and although the shape of each curve will be affected by the presence of all the loads it will depend only upon their final values, variable loading orders having been eliminated. Then, if s is one of the points r, $\delta_s = \delta_s(\gamma, P_r, P_s, P_t, \ldots)$; and, conversely, R_s corresponding to a given γ depends upon all the ultimate displacements, $R_s = R_s(\gamma, \Delta_r, \Delta_s, \Delta_t, \ldots)$, or, since $\gamma = \frac{\delta_s}{\Delta_s}$,

$$R_s = R_s(\delta_s, \Delta_r, \Delta_s, \Delta_t, \ldots).$$

With the deformation built up in this way,

$$\left.\begin{aligned} V &= V_o - \sum_r \int_0^{\Delta_r} P_r\,(\delta_r)\,d\delta_r \\ U &= U_o + \sum_r \int_0^{\Delta_r} R_r\,(\delta_r)\,d\delta_r \end{aligned}\right\} \quad (2)$$

where $R_r(\delta_r)$ is an abbreviation for $R_r(\delta_r, \Delta_r, \Delta_s, \ldots)$, representing a single definite curve.

If the external forces, P_r, do not vary with the displacements, δ_r, then

$$V = V_o - \sum_r P_r\,\Delta_r.$$

If the structure has a linear reaction/displacement curve,

$$R_r(\delta_r, \Delta_r, \Delta_s, \ldots) = \delta_r.\,k_r(\Delta_r, \Delta_s, \ldots),$$

and U simplifies to

$$\begin{aligned} U &= U_o + \tfrac{1}{2}\sum_r \Delta_r\,R_r\,(\Delta_r) \\ &= U_o + \tfrac{1}{2}\sum_r P_r\,\Delta_r \end{aligned}$$

since Δ_r is the displacement which makes $R_r = P_r$.

Note that it is always theoretically possible to keep any or all of the displacements proportional to γ, simply by considering each point involved as a loaded point, whose load may return to zero at full displacement. Provided the final deformation is not changed the strain energy is the same no matter how many loads have been introduced to form the deformation.

COMPLEMENTARY ENERGY

The complementary energy of an initially unstressed structure subjected to a single point load P is defined as $S = \int_0^P \delta\,(R)\,dR$ where δ, the displacement under the load, is expressed as a function of the reaction under the load. The area OAB above the reaction/displacement curve, Fig. 4, is then a measure of S, whereas U is given by the area below it. If P is the total load finally applied to the structure and Δ is its displacement, so that $P(\Delta) \equiv P$, we have, from Fig. 4,

$$U + S = P\Delta \quad . \quad . \quad (3)$$

If there are several loads, S is defined by

$$S = \sum_r \int_0^{P_r} \delta_r\,(R_r)\,dR_r$$

a function of the external forces, P_r, and elastic

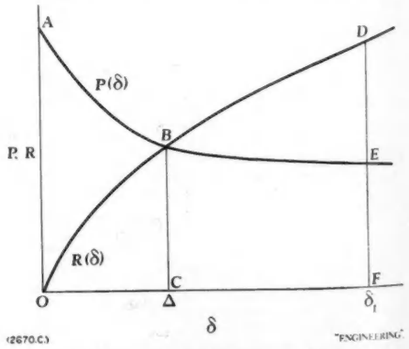

Fig. 3 The loss of potential energy of a suddenly-applied force is represented by the area OAEF; the gain in strain energy by ODF. At the displacement δ_1 the two are equal: the kinetic energy is zero and the structure is momentarily at rest.

properties of the structure only, where $\delta_r(\mathrm{R}_r)$ expresses the relation between δ_r and R_r when all the displacements increase together as discussed in the last section. For the particular case of a structure obeying Hooke's law the curves OB become straight lines, and $\mathrm{S} = \mathrm{U} = \frac{1}{2}\sum_r \mathrm{P}_r\Delta_r$. There is then no advantage in considering complementary energy at all. In other, non-linear, cases we have seen that the stiffness of the structure to loads P_r is not independent of the self-straining, which must therefore be considered from the start.

The complementary energy of a self-strained structure is found by imagining such initial cuts as would release all the self-straining, giving dislocations at sundry points *i*. Then when forces P_r are applied they must be accompanied by equal and opposite pairs Q_i so as just to close the gaps in the loaded structure. The external forces Q_i can be removed if the cuts are cemented, and the deformations and stress distribution will be unaltered. Displacements are now measured from the unloaded position of the *cut* structure and are denoted by *d* and D, corresponding respectively to δ and Δ, which are reserved for displacements from positions in the unloaded *self-strained* structure. If the internal redundant forces, Q_i, are considered as external loads, and $d_i(\mathrm{R}_i)$, $d'_i(\mathrm{R}'_i)$ give their displacements corresponding to reactions R_i, R'_i of the structure, the total complementary energy becomes

$$\mathrm{S} = \sum_r \int_0^{\mathrm{P}_r} d_r(\mathrm{R}_r)\, d\mathrm{R}_r + \sum_i \left\{ \int_0^{\mathrm{Q}_i} d_i(\mathrm{R}_i)\, d\mathrm{R}_i + \int_0^{\mathrm{Q}_i} d'_i(\mathrm{R}'_i)\, d\mathrm{R}'_i \right\}. \quad (4)$$

If the initial gap at *i* in the line of action of Q_i was λ_i, then when R_i and R'_i reach the value of Q_i (which they must do simultaneously although they may not have grown at the same rate) we shall have

$$d_i(\mathrm{Q}_i) + d'_i(\mathrm{Q}_i) = \lambda_i.$$

It is shown in Appendix II that for an elastic structure S is independent of the manner in which the deformation is built up, and we may therefore find an alternative expression for it. As before we imagine the self-straining to be released by initial cuts, but this time we apply first such pairs of forces Q_{i0} as will close the gaps in the otherwise unloaded structure. Then

$$\mathrm{S}_0 = \sum_i \left\{ \int_0^{\mathrm{Q}_{i0}} d_{i0}(\mathrm{R}_i)\, d\mathrm{R}_i + \int_0^{\mathrm{Q}_{i0}} d'_{i0}(\mathrm{R}'_i) d\mathrm{R}'_i \right\}.$$

We write $\mathrm{d}_{i0}(\mathrm{R}_i)$ now instead of $d_i(\mathrm{R}_i)$ because the displacement associated with a given reaction R_i is different from the value it had in equation 4, where the external forces, P_r, were also on the structure. When these forces are applied together with increments to the internal redundant forces, Q_{i0}, so as to keep the gaps closed and build up the full deformation, the increase in complementary energy is

$$\sum_r \int_0^{\mathrm{P}_r} \delta_r(\mathrm{R}_r)\, d\mathrm{R}_r + \sum_i \int_{\mathrm{Q}_{i0}}^{\mathrm{Q}_i} \{\delta_i(\mathrm{R}_i) + \delta'_i(\mathrm{R}_i)\}\, d\mathrm{R}_i.$$

The symbols δ now are used for displacements, since they are measured from the unloaded position of the self-strained structure. The positive directions of δ and δ' are opposite, being the same as those of the corresponding forces Q, which are opposed to each other. As the gaps were kept closed during the application of the external forces it follows that $\delta_i + \delta'_i \equiv 0$, and the second term in the expression above vanishes. The alternative expression for the total complementary energy therefore reduces to

$$\mathrm{S} = \mathrm{S}_0 + \sum_r \int_0^{\mathrm{P}_r} \delta_r(\mathrm{R}_r)\, d\mathrm{R}_r. \quad . \quad (5)$$

It is essential to note three points in connection with equations 4 and 5: first, that $\delta_r(\mathrm{P}_r) \neq d_r(\mathrm{P}_r)$, that is, $\Delta_r \neq \mathrm{D}_r$; second, that for a non-linear structure $\delta(\mathrm{R})$, the displacement for a given reaction R, depends on the amount of self-straining; third, that $d_r(\mathrm{R}_r)$ and $\delta_r(\mathrm{R}_r)$ should strictly be written

$$d_r(\mathrm{R}_r, \mathrm{P}_r, .. \mathrm{Q}_i, ..), \quad \delta_r(\mathrm{R}_r, \mathrm{P}_r, .. \mathrm{Q}_i, ..).$$

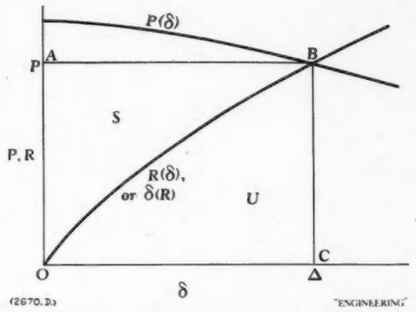

Fig. 4 The complementary energy is given by the area OAB, the strain energy by the area OBC. Taken together, they equal the product of the applied load and its deflection.

EXPRESSIONS FOR COMPLEMENTARY ENERGY

Before any use can be made of the complementary energy, it must be expressed in terms of the internal forces or the displacements of the structure. This is not immediately possible, for the complementary energy is not covered by the conservation of energy principle, since it does not represent work actually done (indeed, in the general case, when P varies with δ, it appears to have no physical significance whatever). Thus whereas we have seen that the strain energy can be found from such expressions as $\int \sigma_x\, d\epsilon_x$ (which represents the area below the stress/strain curve) there is so far no justification for similarly deriving the complementary energy from $\int \epsilon_x\, d\sigma_x$ (the area above the stress/strain curve).

It is shown in Appendix III, however, that such expressions are valid, provided all the strains are proportional to γ when the displacements increase together as described above ("Several Applied Loads"). We have seen that it is always possible to keep all the displacements proportional to γ, and so the strains can only fail to be similarly proportional if the displacements are large (*cf.* Charlton[2]). The proviso may alternatively be stated as requiring superposition to hold between displacements and strains, but as Westergaard[3] pointed out, this is only a limited form of superposition and does not require a linear stress/strain relation.

Then when the displacements are small we may write

$$d\mathrm{S} = dx\, dy\, dz \int (\epsilon_x d\sigma_x + \epsilon_y d\sigma_y + \epsilon_z d\sigma_z + \gamma_{xy} d\tau_{xy} + \gamma_{yz} d\tau_{yz} + \gamma_{zx} d\tau_{zx}) \quad (6)$$

and integrate throughout the volume of the structure to find S (*cf.* equation 1 for finding U).

With the same restriction of proportionality of extensions to the displacements of the loads it is shown in Appendix III, page 308, that

$$\mathrm{S} = \sum_n \int_0^{\mathrm{T}_n} e_n\, d\mathrm{T}_n \quad . \quad . \quad (7)$$

(where T_n is an internal force and e_n the corresponding displacement) with the added condition that the strain energy must be expressible as

$$\sum_n \int_0^{e_n} \mathrm{T}_n\, de_n.$$

For example, consider a statically-determinate frame of *n* pin-jointed members with loads applied at the node points, and let the extension of each member be proportional to the square of the tension in the member, so that $e_n = k_n \mathrm{T}_n^2$. This satisfies both of our conditions, provided the deformation is not large enough to change the geometry of the structure, and

$$\mathrm{S} = \sum_n k_n \int_0^{\mathrm{T}_n} \mathrm{T}_n^2\, d\mathrm{T}_n = \tfrac{1}{3} \sum_n k_n \mathrm{T}_n^3.$$

It may be mentioned here that the treatment in Appendix III differs from that of previous writers (for example, references 2 and 3) in avoiding recourse to the theorem of Virtual Work. This is an advantage to the later discussion of the physical significance of the complementary energy theorems.

APPENDIX I

Uniqueness of Strain Energy for a Given Deformation

Consider an elastic structure to which several loads P_r are to be applied in a specified order, so that the deformation has one definite form. It is required to prove that the strain energy of the structure in this given deformation is independent of the manner in which that deformation is reached.

Let U_0 be the initial energy of self-straining, if any. Let the loads be applied "slowly" in the specified order, and plot the reaction/displacement curve for each of the loading points *r*. If the resulting displacements are denoted by Δ_r, the strain energy is

$$\mathrm{U}_1 = \mathrm{U}_0 + \sum_r \int_0^{\Delta_r} \mathrm{R}_r(\delta_r)\, d\delta_r.$$

Now let the loads be slowly removed in any order. New loads may be introduced during this process, if desired, so that the deformation may be annulled by any route; the only stipulation is that ultimately all the loads are removed, so that since the structure is elastic the entire deformation will disappear and the strain energy will return to U_0. The reaction/displacement graphs will have traced out new curves, but the total work done by all the reactions must have been $\mathrm{U}_1 - \mathrm{U}_0$.

Finally let the same deformation be reached again by reversing the second, arbitrary, route. As every interim deformation must correspond to a unique set of external loads the reaction/displacement graphs must retrace their curves, the total area under which we have seen to be $\mathrm{U}_1 - \mathrm{U}_0$. The strain energy thus returns to U_1 when the full deformation is reached, and since the deformation was built up in an arbitrary manner this proves the theorem.

Note that it was specified that the same deformation be built up a second time, not that the same loads be applied again. This is because the deformation for a given set of loads is not necessarily unique, and when the loads were applied in the reverse of the previous unloading order the structure might have preferred a new deformation. In this case the original deformation could be regained by this loading order only if, during part of the loading procedure, certain constraints were supplied so as to prevent deflection into the preferred form. It is remarkable that since the interim deformations were reached during unloading without the constraints acting, and since to each interim deformation there corresponds a unique set of loads, the forces involved in the constraints must all be zero.

This does not mean that the constraints do not exist. In the desired deformation they exert no force, but they must have a "stiffness," so that the smallest departure from the desired deformation will incur a correcting force from the constraint.

APPENDIX II

Uniqueness of Complementary Energy for a Given Deformation

Consider an elastic structure to which several loads are to be applied in a specified order, so that the deformation has one definite form. It is required to prove that the complementary energy of this given deformation is independent

of the manner in which the deformation is reached.

Let the loads be applied "slowly," and let the deformation be reached by any, arbitrary, route. The reaction/displacement graphs may be plotted, and the total areas above and below the curves give the changes in complementary and strain energy;

$$S_1 = S_0 + \sum_r \int_0^{P_r} \delta_r\,(R_r)\,dR_r$$

$$U_1 = U_0 + \sum_r \int_0^{\Delta_r} R_r\,(\delta_r)\,d\delta_r .$$

Then since (*cf.* Fig. 4)

$$\int_0^P \delta\,dR + \int_0^\Delta R\,d\delta = P\,\Delta$$

$$S_1 = S_0 + U_0 + \sum_r P_r\,\Delta_r - U_1 .$$

S_0 and U_0 are constants; the deflections Δ_r are fixed, and the forces P_r corresponding to a given deformation are unique; U_1 was shown to be unique in Appendix I. It follows that S_1 is unique, that is, independent of the manner in which the deformation is built up.

APPENDIX III

Expressions for Complementary Energy

Consider an elastic structure from which all self-straining has been released by suitable cuts at points i. Let the loads P_r be applied "slowly" and simultaneously with the requisite pairs of forces Q_i to close the gaps, and let all the displacements, measured from the unstressed cut configuration, be kept proportional to a variable γ, increasing from zero to their final values as γ increases from 0 to 1. Then with the notation explained in the derivation of equation (4), $d_r = \gamma\,D_r$ and $dd_r = D_r d\gamma$.

An increase in γ increases all the displacements uniformly, and during the growth of the deformation, when $\gamma < 1$, the strain energy may be written

$$U(\gamma) = \sum_r D_r \int_0^\gamma R_r(\gamma)\,d\gamma + \sum_i \left\{ D_i \int_0^\gamma R_i(\gamma)\,d\gamma + D_i' \int_0^\gamma R_i'(\gamma)\,d\gamma \right\}$$

where $R(\gamma)$ represents the reaction at a given value of γ. Then

$$\frac{dU}{d\gamma} = \sum_r D_r R_r(\gamma) + \sum_i \{D_i R_i(\gamma) + D_i' R_i'(\gamma)\}$$

and

$$\gamma\frac{dU}{d\gamma} = \sum_r d_r R_r(\gamma) + \sum_i \{d_i R_i(\gamma) + d_i' R_i'(\gamma)\}. \quad . \quad . \quad . \quad (33)$$

Also, when $\gamma < 1$, referring to Fig. 4, page 307, and equation (3),

$$U(\gamma) + S(\gamma) = \sum_r d_r R_r(\gamma) + \sum_i \{d_i R_i(\gamma) + d_i' R_i'(\gamma)\},$$

or, combining this with equation (33),

$$S(\gamma) = \gamma\frac{dU}{d\gamma} - U(\gamma). \quad . \quad (34)$$

It was shown in equation (1) that the strain energy can be expressed as the sum of terms of the form $\int_0^\epsilon \sigma\,d\epsilon\,dx\,dy\,dz$ integrated throughout the structure. Sometimes this volume integration can be replaced by the sum of a number of terms involving certain internal forces T_n and corresponding extensions e_n, and the expression for U is $\sum_n \int_0^{e_n} T_n\,de_n$. The strain energy of a pin-jointed frame, for instance, would be found in this way, the summation covering the n members of the frame. If we can now show that under certain conditions $\gamma\frac{dU}{d\gamma}$ equals $\sum_n T_n(\gamma)\,e_n(\gamma)$, or can be found by volume integration of terms such as $\sigma(\gamma)\,\epsilon(\gamma)$, then from equation (34),

$$\left.\begin{aligned} S(\gamma) &= \sum_n \left\{ T_n(\gamma)\,e_n(\gamma) - \int_0^{e_n(\gamma)} T_n\,de_n \right\} \\ &= \sum_n \int_0^{T_n(\gamma)} e_n\,dT_n \end{aligned}\right\} \quad (35)$$

or similarly

$$S(\gamma) = \iiint \left\{ \int_0^{\sigma_x(\gamma)} \epsilon_x\,d\sigma_x + \ldots + \ldots \right\} dx\,dy\,dz$$

giving useful expressions for applications. It remains to find under what conditions these expressions are valid.

If $U(\gamma)$ can be expressed as $\sum_n \int_0^{e_n(\gamma)} T_n\,de_n$

$$\frac{dU}{d\gamma} = \sum_n \frac{\partial U}{\partial e_n}\frac{de_n}{d\gamma} = \sum_n T_n(\gamma)\frac{de_n}{d\gamma}.$$

Then

$$\gamma\frac{dU}{d\gamma} = \sum_n T_n(\gamma)\,e_n(\gamma) \text{ if } \gamma\frac{de_n}{d\gamma} = e_n(\gamma).$$

During the loading the displacements are kept proportional to γ, but this is not necessarily so of the strains ϵ or of the extensions e_n, which may be expressed in general by a MacLaurin series, thus

$$e_n(\gamma) = \gamma\,e_n'(0) + \frac{\gamma^2}{2!}e_n''(0) + \frac{\gamma^3}{3!}e_n'''(0) + \ldots$$

where $e_n = 0$ when $\gamma = 0$.

$$\frac{de_n}{d\gamma} = e_n'(0) + \gamma\,e_n''(0) + \frac{\gamma^2}{2!}e_n'''(0) + \ldots$$

so that

$$\gamma\frac{de_n}{d\gamma} = e_n(\gamma) \text{ only if } e_n''(0) = e_n'''(0) = \ldots = 0,$$

in which case,

$$e_n(\gamma) = \gamma\,e_n'(0) = \text{constant} \times \gamma. \quad . \quad (36)$$

The condition for the validity of expressions (35) therefore is that the extensions e_n (or, by a similar analysis, the strains ϵ) shall always be proportional to γ, that is, to the deflections d_r and d_i.

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Parts 2 and 3 of this article will be published in subsequent issues.

★ ★ ★

SPHEROIDAL-GRAPHITE CAST IRON

Properties and Applications: Film

The main features of the process for the manufacture of spheroidal-graphite cast iron by the treatment of the molten iron with magnesium, and the properties of the resultant material, are the subject of a 16-mm. colour cinema film with sound commentary, entitled "S.G. Iron: Cast Iron that Bends," shown in London recently.

Foundry production, including the magnesium addition, is illustrated, and the properties typical of the iron are demonstrated by a series of bending, twisting, impact, shock, tensile and machining tests. Some of the many applications in which the material is utilised are then shown.

The film, which runs for 17 minutes, has been prepared by the Mond Nickel Company, Limited, Thames House, Millbank, London, S.W.1, and is now available, on loan, to technical societies, colleges and schools.

LAUNCHES AND TRIAL TRIPS

M.S. "BELFAST."—Single-screw oil tanker, built and engined by Harland and Wolff, Ltd., Govan, Glasgow, for Belships Co. Ltd. Skibs A/S, Oslo, Norway. Main dimensions: 540 ft. between perpendiculars by 73 ft. by 39 ft. 3 in.; deadweight capacity, about 18,500 tons. Harland-B. and W. six-cylinder single-acting two-stroke oil engine. Trial trip, February 23.

H.M.S. "LEVERTON."—Twin-screw coastal minesweeper, built by Harland and Wolff, Ltd., Belfast, for the Admiralty, London, S.W.1. Main dimensions: 152 ft. by 28 ft. 9 in., by 14 ft. 9 in., armament, three small guns. Diesel propelling machinery supplied by Mirrlees, Bickerton and Day, Ltd., Stockport, Cheshire. Launch, February 23.

M.S. "BOSTON NEPTUNE."—Single-screw trawler, built by the Goole Shipbuilding and Repairing Co., Ltd., Goole, for the Boston Deep Sea Fishing and Ice Co., Ltd., Fleetwood. Main dimensions: 128 ft. by 26 ft. 6 in. by 13 ft. Diesel propelling machinery constructed by Mirrlees, Bickerton and Day Ltd., Stockport, Cheshire. Speed, 12 knots. Launch, February 23.

M.S. "MOUNT EVEREST."—Single-screw trawler, built by John Lewis and Sons, Ltd., Aberdeen, for the Seafield Fishing Co., Ltd., Aberdeen. First vessel to be built under the White Fish Authority's grant and loan scheme for Aberdeen ownership. Main dimensions: 120 ft. between perpendiculars by 25 ft. by 12 ft. 6 in.; fishroom capacity, 7,000 cub. ft. Mirrlees six-cylinder direct-drive and reversing Diesel engine, developing 650 b.h.p. at 250 r.p.m., constructed by Mirrlees, Bickerton and Day, Ltd., Stockport, Cheshire. Launch, February 24.

M.S. "NAVUA."—Single-screw cargo vessel, built by Henry Robb, Ltd., Leith, for the coastal services of the Union Steam Ship Co. of New Zealand, Ltd., Wellington, New Zealand. Main dimensions: 250 ft. between perpendiculars by 41 ft. 6 in. by 17 ft. 9 in. to upper deck; deadweight capacity, about 2,000 tons on a mean draught of 16 ft. Clark-Sulzer five-cylinder two-stroke Diesel engine, developing 1,500 b.h.p. at 225 r.p.m., constructed by George Clark (1938), Ltd., Sunderland. Speed, 11 knots. Launch, February 24.

H.M.S. "MURRAY."—Anti-submarine frigate, built by Alexander Stephen and Sons, Ltd., Govan, Glasgow, for the Admiralty, London, S.W.1. Length 310 ft. overall, and beam 33 ft. Armament comprises three Bofors guns and two three-barrelled anti-submarine mortars. Propulsion provided by geared steam turbines constructed by the shipbuilders. Launch, February 25.

H.M.S. "EXCALIBUR."—Submarine, built and engined by Vickers-Armstrongs Ltd., Barrow-in-Furness, for the Admiralty, London, S.W.1. Extreme length 225 ft. 6 in. and with a beam of nearly 16 ft. In addition to her Diesel-electric propelling machinery, the vessel is fitted with turbine machinery for which the energy is supplied by burning Diesel fuel in decomposed hydrogen peroxide. Launch, February 25.

M.S. "PORT SYDNEY."—Twin-screw cargo vessel built by Swan, Hunter, and Wigham Richardson, Ltd., Wallsend-on-Tyne, for the Port Line, Ltd., London, E.C.3. Main dimensions: 498 ft. between perpendiculars by 70 ft. by 42 ft. to upper deck; deadweight capacity, 11,120 tons on a draught of about 28 ft. 10 in.; refrigerated-cargo space, 334,500 cub. ft.; unrefrigerated-cargo space, 295,800 cub. ft.; gross tonnage, 9,992. Two Wallsend-Doxford six-cylinder single-acting two-stroke oil engines, together developing 13,200 b.h.p. at 112 r.p.m., constructed and installed by the Wallsend Slipway and Engineering Co., Ltd., Wallsend-on-Tyne. Service speed, 17 knots. Trial trip, February 28.

M.S. "PRINCESS OF VANCOUVER."—Twin-screw vehicular and train ferry, with accommodation for 800 passengers, built by Alexander Stephen and Sons, Ltd., Govan, Glasgow, for the Vancouver to Nanaimo, British Columbia, service of the Canadian Pacific Railway Co., Montreal. Main dimensions: 388 ft. between perpendiculars by 63 ft. by 19 ft. 6 in. to upper deck; draught 14 ft. 9½ in. Four seven-cylinder non-reversing Diesel engines, working through Vulcan-Sinclair type hydraulic couplings and hydraulically-operated reverse-reduction gearing coupled to twin propeller shafts. Main engines, constructed by the National Gas and Oil Engine Co., Ltd., Ashton-under-Lyne, develop a maximum of 5,600 s.h.p. at 333 r.p.m., and are arranged to operate on bunker or Diesel fuel. The couplings were manufactured by the Fluidrive Engineering Co., Ltd., Isleworth, Middlesex, and the gearing by the Modern Wheel Drive, Ltd., Chesham, Buckinghamshire. Service speed, 15¼ knots. Launch, March 7.

INVERTING A 256 × 256 MATRIX*

SOLUTION OF AN ENGINEERING SYSTEM BY METHOD OF SECTIONS USING A CARD PROGRAMME CALCULATOR

By Gabriel Kron†

A symmetrical matrix with 256 rows and columns was effectively inverted on a Card Programme Calculator (CPC) in slightly less than 16 hours machine time. The procedure followed was that of the "method of tearing," or "method of sections." The resulting matrices represent a factorised form of the conventional inverse matrix and contain less than 20 per cent. of the non-zero elements of the latter. The rounding-off errors amounted to only about four figures out of eight. Two important labour-saving devices for tearing physical systems or their electric-circuit models apart are also described.

THE METHOD OF TEARING

This article reports the results of an unusual analytical experiment, the purpose of which was to extend the workable range and speed of existing digital computers in the solution of engineering systems by a large factor, as yet unpredictable. In particular, this paper describes the steps used to invert in effect a symmetrical matrix with 256 rows and columns (representing the diffusion equations of a cylindrical nuclear reactor) on a Card Programme Calculator (CPC) in slightly less than 16 hours of actual machine time. It is emphasised that the new form, in which the results of the inversion are expressed, differs from the conventional "inverse" matrix. The new form, called "orthogonal" or "factorised" inverse, is a table of several matrices in which the number of non-zero elements is only a small fraction of the number occurring in a conventional inverse matrix. For all manipulative and computational purposes the inverse table takes the place of an inverse matrix.

Since the largest actual products and inversions that could be undertaken on the CPC throughout the procedure are those of 16 × 16 matrices, the increase in possible size factor (number of equations) that the machine has handled for inversion is 16. This number, however, is still short of the possible maximum.

The method consists of tearing apart, or sectioning, the physical system (not the equations) into a large number of independent smaller systems and solving the equations of each partial system separately (either numerically, or analytically) as if the other component systems were non-existent.

The partial solutions are then interconnected by a set of transformations into the solutions of the entire original system. (In linear problems the transformations assume a simple form such as $\mathbf{C}_t \mathbf{Z} \mathbf{C}$, but in non-linear problems the laws of transformations are more complicated.) After interconnection it is still necessary to solve for, or eliminate, the comparatively few constraint variables introduced at the cuts. This last step may also be performed by further tearing apart the additional physical system formed by the cut boundaries.

When a change is made on the already solved system, the calculations are not started all over again; only those portions of the solution are changed that correspond to the physical change. An increase or decrease in the system size is followed in parallel by a similar change in the corresponding part of the solution.

A detailed examination of the correctness of this method has already been published by the author[1, 2]. The actual steps used here follow closely those given for the solution of the field equations of Maxwell which have also been previously discussed by the author[2]. The reader is referred to these three publications for the detailed steps involved in the tearing method. The present article puts on record the results of an actual study and a check on the results. Some labour-saving steps are also described which have not been given previously. The analytical method of solution will be discussed in a future publication.

MODELS OF THE SYSTEM

It should be emphasised that it is the physical system itself—or a model of it—that is torn apart and not the equations. Expressed in another way, the method of tearing has no relation whatever to the "partitioning" of matrices. (As a matter of fact, the equations of the entire system are never even written down in the new method, but only those of the subdivisions that are dissimilar.) The basic difference between these two processes is due to the fact that the partitioning of matrices does not contribute any new information or equation about the physical system, but the tearing apart of a model does. Indeed, the entire method of tearing is built upon the availability of the extra information, namely, the constraints appearing at the points of tear.

An electric-circuit model has been found quite satisfactory for the purposes of tearing, but other types of model could be employed as well. The model itself exists only on paper and need not be physically realisable, being only a schematic representation of the geometrical configuration of the given physical system. Thus the model torn apart is only a "topological" model employing, however, electrical nomenclature instead of geometrical.

PURPOSE OF TEARING

To avoid any misunderstanding, it must be stated that the "method of tearing" is not intended to compete with any existing numerical or analytical, exact or iterative, method of inversion or solution. The numerical tearing method has been devised to be introduced only when a problem is so large that other methods exceed the capacity of the available computer, be it a slide-rule, a desk calculator or an electronic computer. The analytical tearing method is to be used only when the physical system has such an odd shape or complexity (or both) that conventional analytical methods fail.

When a complex linear system is torn apart into several components, in many cases it is possible to remove from each component part some, or all, of the parameters (if there are not too many) like thermal conductivity, diffusion or absorption constant, length, height and thickness, etc. If the remaining numerical matrix of each isolated part is inverted and their inverse matrices are interconnected, the removed parameters can be re-inserted into the resultant inverse matrix with comparatively little and often with no extra labour.

In many non-linear systems, it is often possible to establish an approximate inverse matrix in easy stages by the method of tearing. Thus the true solution may be approached by generalising the standard successive approximation methods to handle very large inverse matrices, defined in several smaller pieces, in a factorised form. It also seems logical that many of the constant parameters could be factored out after the tearing apart and re-substituted into the approximate inverse matrix. These constant parameters may represent for instance the geometrical shapes and dimensions of containers, or of bodies immersed in fluids and gases.

The method of tearing is to be used when the problem has special attributes, e.g., frequent variations in composition of the different portions, movement of parts, changes in boundaries, or in structure, etc. The author visualises its use, for instance, in cases where it is intended to accumulate already established solutions ("equations of solutions") to build up the equations of solutions of still bigger structures, without starting the solution from the very beginning all over again for each larger structure. Moreover, most of the large physical systems are so interwoven that even the writing down of the "equations of state" is a well-nigh hopeless undertaking; the method of tearing is ideal for the solution of such extensive and undescribable systems. For instance, to solve a complex two- or three-dimensional elastic structure with hundreds of beams, the method of tearing needs only the six (or rather twelve) basic equations of each isolated beam. The interconnections, needed to establish both the equation of state and the equation of solution of the entire system, are all automatically taken care of by a series of "connection tensors," $\mathbf{C}$, which are easily constructed by mere inspection. The latter contain chiefly plus or minus unity and zero as their elements.

The present example of tearing should not be regarded as attempting to compete with other methods already devised for the particular example of this article. It so happens that this example is applied to an extremely simple network of points with regular internal and external geometry. It is evident that special methods, such as the "partitioning of matrices," can reduce the calculation of this particular inverse to a fraction of that of a full matrix. Also, the present simple circuit may be solved (not inverted) by various iterative methods at speeds far exceeding that of the inversion method shown. If, however, a larger number of solutions are wanted the present method could become competitive.

In the present example the same transformations and the same quasi-diagonal matrices appear whenever the system is asymmetrical and the subdivisions irregular, and the cut boundaries are forced to follow arbitrary paths by an arbitrarily curved reference frame. The chief aim of the present analysis is to establish the final inverse matrix in such an almost-empty quasi-diagonal form that it could be re-employed for the solution of still larger physical systems. The author visualises, for instance, the re-use of quasi-diagonal inverse matrices of two-dimensional structures for the inverse calculation of three-dimensional structures (the third dimension may be energy, or space, or time) and the latter in turn to be used eventually for four-dimensional problems. To solve successfully such extensive problems, it is imperative that all the inverses should contain as few non-zero elements as possible. The present method does supply such quasi-diagonal inverses.

Moreover, the factorised inverse can be established much faster than other methods could construct a conventional inverse. Compared with the Gauss or Crout elimination process, the method of tearing is faster (in two-dimensional field problems at least) by a factor of about $\frac{2}{n^2}$, where n is the number of subdivisions. Of course, compared with other specialised types of inversion methods, such as the partitioning of matrices, or triangulation, the factor is less favourable for the method of tearing. The speed ratio depends on the nature of the original sub-matrices, on the regularity and number of non-zero terms and so on. The calculation time of the factorised inverse is, however, not sensitive to variations in the above characteristics, and the speed-factor increases in its favour with the generality of the sub-matrices.

To avoid further misunderstanding, it must also be emphasised that the method of tearing is primarily an inversion process and not merely a solution technique. Its primary purpose is to establish a new type of inverse matrix that can be utilised efficiently for other purposes besides giving a series of particular solutions for a number of different boundary conditions. For instance, for a nuclear reactor it is intended

* The work was done for the Knolls Atomic Power Laboratory operated for the United States Atomic Energy Commission by the General Electric Company, Contract No. W-31-109 Eng. 52.

† Consulting Engineer, General Electric Company, Schenectady, New York, U.S.A.

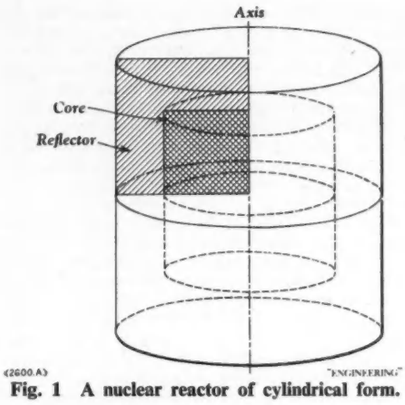


Fig. 1 A nuclear reactor of cylindrical form.

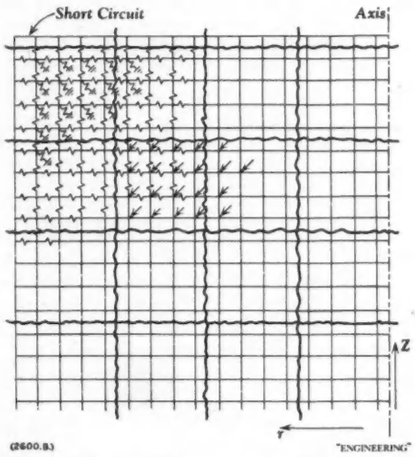


Fig. 2 The 256-point net representation of the partial-differential equation formed for the nuclear reactor of Fig. 1. The subdivision of the electric-circuit model into sub-circuits which can be considered for calculation is shown here.

to set up the inverse matrices of the core, reflector, control and other parts separately for various materials, then interconnect the inverse matrices in various combinations. Movable controls may be interconnected with the rest of the reactor in a large number of positions, without repeating any of the calculations for the stationary or movable parts. In such manipulations a factorised inverse can be utilised far more effectively than is possible with a conventional inverse.

"DIAKOPTICS"

The author has applied the method of tearing to set up the "equations of state" of a large variety of linear and non-linear physical systems. The same methods have been applied with increasing frequency to set up the "equations of solutions" of many types of linear systems. Special non-linear dynamical systems have also been analysed—and in one simple case were also solved[6]—by the method of tearing. There seems to be no logical reason why the method could not be applied to the solution of more general types of non-linear systems also. The application of the method has occasionally involved the most abstract concepts of the calculus of tensors and the algebra of matrices and tensors.

The author would like to term the new method by the Greek name "*Diakoptics*."* It comes from the word "kopto" meaning "to break," or "to tear apart"; the prefix "dia" merely reinforces the word to follow, as the English "very."

As the labour-saving device at the end of this article will show, the concept of "breaking-up" a physical system means more than a separation into isolated subdivisions. It also means a temporary destruction of non-essential portions, a transformation of entire subdivisions into new and more convenient reference frames—in short, a genuine "break-up" of the original system whose solution is sought. These physical changes, however, can all be fitted smoothly into the framework of the calculus of tensors, so that the final solutions come out in an exact form, as if the entire original system had been solved outright as one integral unit. No approximations are involved in these unorthodox manipulations of physical structures.

* The name was suggested by Professor Philip Stanley, of the Department of Philosophy, Union College, Schenectady, New York.

PROCEDURE

The Problem.—The problem under consideration is the 256-point net representation, depicted in Fig. 2 herewith, of the partial-differential equation of a nuclear reactor with cylindrical shape, Fig. 1:—

$$\text{Div } \mathbf{y} \text{ grad } E + b\,E = I$$
$$a\,\nabla^2 E + b\,E = I$$

The difference equations assume the form $\mathbf{I} = \mathbf{Y}\,\mathbf{E}$.

A detailed study of the electric circuit has already been given.[4] The succession of steps for solving the circuit have also been given[2] in connection with solving the field equations of Maxwell by analogous steps. Some of the non-conventional steps and labour-saving devices employed will be discussed, however, in greater detail later.

Solution of the Subdivisions.—The network was subdivided into 16 parts, as shown in Fig. 2. Since the upper boundary contained a short-circuit, it was found to be expedient to form also four additional smaller subdivisions. In this way four of the large subdivisions lying along the z-axis became identical so that the 16 large divisions needed only four different networks for representation. The extra variables due to the boundary cuts have been temporarily ignored by employing the method shown at the end of the paper.

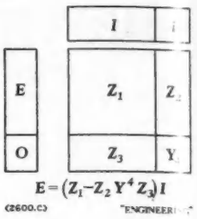
The solutions of the 16 large subdivisions thus involved the inversion of four different 16×16 matrices, each taking about 1 hour and 10 minutes CPC time, thereby establishing the $\mathbf{Z}_1$ portion of the "orthogonal" inverse table, shown in Figs. 3 and 4.

Interconnection.—The interconnection is performed by $\mathbf{C}_t\,\mathbf{Z}\,\mathbf{C}$, where $\mathbf{C}$ involves only plus or minus unity or zeros. That is, the interconnection involves no products, only a re-arrangement of some of the rows and columns of the component inverse matrices. The re-arrangement was performed by printing a large number of copies of these matrices, then forming the rest of the resultant $\mathbf{Z}$ with scissor and scotch-tape out of the partial matrices, as dictated by the components of $\mathbf{C}$.

The $\mathbf{Z}_2$, $\mathbf{Z}_3$ and $\mathbf{Z}_4$ portions of the "orthogonal" inverse table of Figs. 3 and 4 have been constructed in this fashion.

Inversion of the Boundaries at the Cut.—The corner matrix $\mathbf{Z}_4$ represents the cut boundary of the physical system and it has 112 rows and columns. This matrix need not be inverted, but only solved by any conventional method. Since it has an almost diagonal form, it is easily solved

Fig. 3 The "orthogonal" inverse.



by the well-known method of "partitioning" a matrix with the aid of submatrices.[5]

The Final Orthogonal Inverse Table.—The orthogonal inverse table involving $\mathbf{Z}_1$, $\mathbf{Z}_2$, $\mathbf{Z}_3$ and $\mathbf{Y}^4$ is shown schematically in Fig. 4. It is a table with $256 + 96 + 16 = 368$ rows and columns. (It is not a matrix.) Nevertheless it only has 14,400 non-zero elements, as against the $256^2 = 65{,}536$ non-zero elements of a conventional inverse matrix. Actually $\mathbf{Y}^4$ had more zero terms than shown, but many of the 4×4 matrices plus zeros were combined into 8×16 matrices to simplify the handling of cards.

For any given $\mathbf{I}$ (a vector with 256 components) the value of $\mathbf{E}$ (also with 256 components) may be found by performing only 14,400 multiplications (or about 15,000 if no 4×4 matrices are used).

ACCURACY OF THE INVERSE

The main purpose of the present study was not to accomplish accuracy, but to prove that the handling of the large number of cards involved in the method was practicable and that the CPC can be used adequately to invert matrices associated with physical systems with at least three to four hundred rows and columns in a comparatively short time. Nevertheless the accuracy of the inverse was quite satisfactory. Starting with constants having eight figures, the entire inverse was accurate to an average of four figures. That is, the rounding-off errors amounted to about four significant figures without the expenditure of any special care. Table I shows 64 given currents $\mathbf{I}$, randomly selected out of the 256 that were substituted into the solution $\mathbf{E} = \mathbf{Z}\,\mathbf{I}$. After calculating all values of $\mathbf{E}$, the latter were re-substituted into the original equations $\mathbf{I} = \mathbf{Y}\,\mathbf{E}$ and the original $\mathbf{I}$ were recalculated. Both sets of $\mathbf{I}$ are given in Table I for comparison.

In considering accuracy, it should be men-

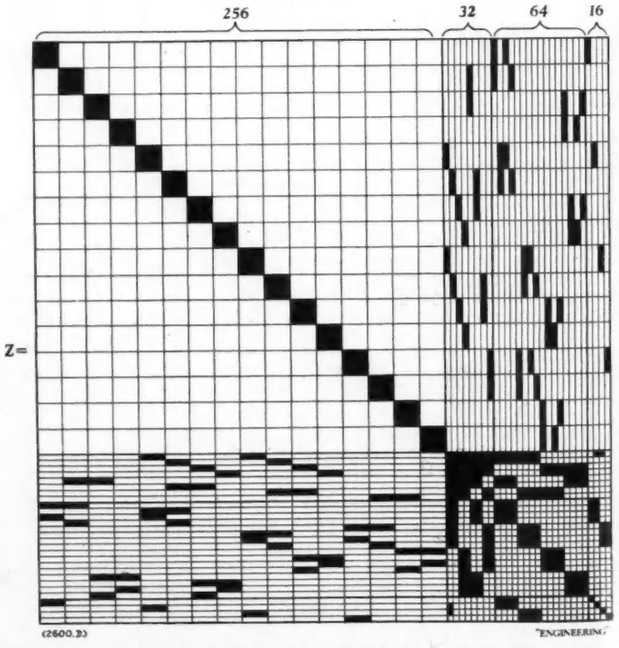


Fig. 4 The actual form of the "orthogonal" inverse of Fig. 3; there are 14,400 non-zero elements.

TABLE I.—ORIGINAL AND CALCULATED VALUES OF I

(Four random I in each of the 16 sub-divisions. First finding **E** from **E** = **ZI**, then finding **I** from **I** = **YE**)

Sub-division	Original I	Calculated I	Sub-division	Original I	Calculated I
I	0·00000000	0·00006	IX	5·0456471	5·0451
	0·00000000	—0·00003		3·5502000	3·550
	0·00000000	0·000014		3·2743920	3·2748
	0·00000000	—0·00002		4·6536608	4·6547
II	0·00000000	0·00005	X	9·5456147	9·5456
	0·00000000	0·00003		8·3472084	8·346
	0·00000000	0·00000		7·6987304	7·6986
	0·00000000	0·00003		8·8040349	8·8025
III	0·00000000	—0·00004	XI	13·377731	13·3751
	0·00000000	0·00013		12·582269	12·5819
	0·00000000	—0·00005		11·604778	11·605
	0·00000000	0·000031		12·338442	12·338
IV	0·00000000	0·00002	XII	15·291773	15·288
	0·00000000	—0·00001		15·013317	15·014
	0·00000000	—0·00008		13·846963	13·848
	0·00000000	0·00006		14·103785	14·100
V	3·2587371	3·2603	XIII	6·0181647	6·0191
	2·2929008	2·2915		4·2344793	4·2339
	2·0826394	2·0818		4·1331297	4·131
	2·9599075	2·9593		5·8741237	5·877
VI	6·1650465	6·1651	XIV	11·385474	11·385
	5·3910544	5·3909		9·9560817	9·9576
	4·8966889	4·8962		9·7177891	9·718
	5·5997051	5·5997		11·112969	11·115
VII	8·6400232	8·6411	XV	15·856207	15·959
	8·0692633	8·0693		15·007425	15·004
	7·3810855	7·382		14·648231	14·649
	7·8477238	7·847		15·574305	15·574
VIII	9·8762094	9·875	XVI	18·239168	18·238
	9·6963686	9·697		17·907042	17·906
	8·8072013	8·807		17·478448	17·474
	8·9705505	8·972		17·802625	17·803

tioned that at several times throughout the procedure it was possible to check the correctness of the results by Kirchhoff's laws. Many random mistakes were discovered, but not corrected, as the errors were thought to be not serious and accuracy was not of primary interest.

Starting with eight figures in **Y**, the inverse matrices in $\mathbf{Z}_1$, $\mathbf{Z}_2$ and $\mathbf{Z}_3$ had six figure accuracy. The second set of inverses in $\mathbf{Y}^4$ had five figure and the third set of 32×32 matrix had about four figure accuracy. The total number of successive inversions were $16 + 4 + 16 + 8 + 16 = 60$. That is, the worst rounding-off error corresponds to that of a conventional inverse with 60 rows and columns. The ratio 60/256 of improved accuracy is independent of the spread of the eigen-values. The final check on accuracy is shown in Table I. The neutron-balance equation

$$\Sigma \text{ source} = \Sigma \text{ absorbed} + \Sigma \text{ leakage}$$

checked to six figures 1312·69228 as compared to 1312·69985.

Apparently the bottleneck to resolve when dealing with really large problems on digital computers consists of this slow accumulation of rounding-off errors when solving for the constraints. It will be worth while to decrease these errors by standard methods, especially toward the last steps where the boundary system involves decreasingly less variables. It is hoped to use eventually a new type of iterative method to invert the electric-circuit models that will not only increase the speed of inversion, but also will slow down still further the accumulation of rounding-off errors.

ESTIMATING MACHINE TIME

To estimate the machine time, two rules of thumb have been found to be of help in finding the factorised inverse of matrices. In particular:

1. If a physical system is torn apart into n parts, its factorised inverse may be found in a fraction of about $\frac{2}{n^2}$ of the inversion time of the Gauss or Crout elimination method. If several of the parts are identical, the saving in inversion time increases proportionally.

2. The number of non-zero elements in the "orthogonal" inverse table is a fraction of about $\frac{1}{\sqrt{n}}$ of that in a conventional inverse matrix.

In two-dimensional partial differential equations these rules have been found to be conservative. When n is too small or too large, the above simple rules need to be modified.

TABLE II.—*Allocation of Machine Time*

Inversion

Type	Number	Time per Matrix	Total Time
16 × 16	9	1 hr. 10 min.	10 hr. 30 min.
8 × 8	2	9 min.	18 min.
4 × 4	4	1·5 min.	6 min.

Total time of inversions, 10 hr. 54 min.

Multiplication

Type	Number	Operation per Matrix	Total Operations
(4 × 4) (4 × 4)	40	64	2,560
(8 × 8) (8 × 8)	6	512	3,072
(16 × 16) (16 × 16)	1	4,096	4,096
(16 × 8 (8 × 4)	16	512	8,192
(4 × 8) (8 × 8)	32	256	8,192

Total number of multiplications: 26,112

Addition

Type	Number	Operation per Matrix	Total Operations
4 × 4	18	16	288
8 × 8	14	64	896
16 × 16	1	256	256

Total number of		
	additions	1,440
	multiplications	26,112
	operations	27,552

Total Machine Time

Assumed Cards/Minute	Time of Operations	Time of Inversions	Total Time
150	3 hr. 3 min.	10 hr. 54 min.	13 hr. 57 min.
125	3 hr. 44 min.	10 hr. 54 min.	14 hr. 38 min.
100	4 hr. 44 min.	10 hr. 54 min.	15 hr. 38 min.

The inversion of a 16×16 matrix on the CPC takes about 1 hour and 10 minutes. Using the Gauss or Crout elimination procedure as a norm for comparison, the time of inversion varies approximately as the cube of the number of variables. Hence the inversions of a 256×256 matrix by standard elimination method should take about $1{\cdot}16 \times 16^3 = 4{,}800$ hours on the CPC. (Of course, other inversion procedures would involve far less time.) As the number of subdivisions n is 16, the method of tearing should involve $\left(\frac{2}{n^2}\right) 4{,}800 = 38$ hours CPC time. The decrease to 16 hours was partly due to the identity of four sets of subdivisions. If all subdivisions had been different, the inversion would have taken about 32 hours. Details of actual machine time is given in Table II.

Since $\sqrt{n} = \sqrt{16} = 4$, the number of non-zero elements should have been $\frac{65{,}500}{4} = 16{,}375$. Actually, it was 14,400, corresponding to a factor 4·5. That means that every time the inverse **Z** table is used to calculate an unknown set of **E** for a given set of **I** (by **E** = **ZI**), the number of multiplications is reduced by a factor of 4·5.

Only about 52 matrices with 6,200 elements had to be actually calculated and recorded, as the remaining 8,400 elements were in matrices that repeated. (Symmetrical matrices were recorded in their entirety.)

TWO LABOUR-SAVING DEVICES

The Removal of Boundary Tie-Lines.—Practical experience with any new method of calculation discloses many unexpected short-cuts and labour-saving devices that are not at all obvious to the inexperienced. A few large-scale examples in setting up factorised inverses have divulged a labour-saving procedure that lead to an unexpected simplification at the very first step of tearing apart a network. These new concepts and methods could probably have never been discovered in the absence of a physical model and are not inherent in the difference equations. These—and most other—labour-saving devices are dictated by the physics of the problem and not by the mathematics itself.

A network, such as Fig. 2, is subdivided by tearing each coil located across the boundaries into two equal (or unequal) parts, so that each cut contributes two extra variables. If, for instance, in Fig. 2, each subdivision has 16 junction points with 16 variables I, the boundaries contribute a maximum of 16 more variables i, so that each subdivision actually contains 32 (or less) variables, instead of 16. In other words, at first sight it appears as if for each subdivision it is necessary to invert, in general, a 32×32 (or slightly smaller) matrix, instead of one of 16×16.

As the solution of a subdivision implies the establishment of an impedance matrix **Z**, knowledge of electrical circuits in general, and of Ohm's law in particular, suggests that the impedances (coils) forming the cut boundaries may be removed bodily from the network before the inversion. That is, the subdivisions may be inverted without the presence of boundary variables, as shown in Fig. 5, so that every **Y** matrix and its inverse **Z** contains only 16 rows and columns.

Re-establishment of Boundaries.—The impedances Z of the removed boundary coils are

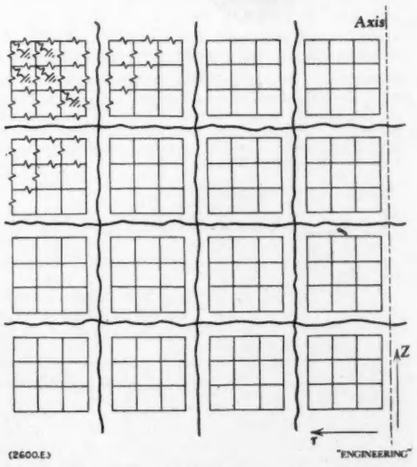


Fig. 5 .The problem has been resolved by " tearing apart " the model which is shown here with the boundary coils removed.

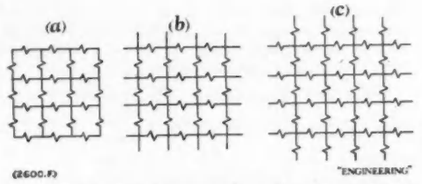


Fig. 6 Re-establishment of the boundary coils in order to interconnect the partial solutions to obtain the solution to the whole problem. (a) Without boundaries. (b) Boundaries with zero Z. (c) Boundaries with actual Z.

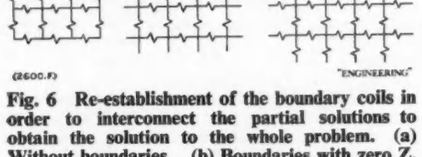


Fig. 7 The subdivided circuits for a simpler problem.

added to the inverse **Z** in two steps. The first step is to add boundary coils having zero impedances, as shown in Fig. 6*b*. That is, each 16 × 16 matrix after inversion is enlarged to a 32 × 32 matrix with the aid of a matrix of transformation **C** that simply doubles or trebles some of the original rows and columns. This matrix is rectangular and has no inverse. For the simpler example of Fig. 7, it has the form (from $\mathbf{i}_{old} = \mathbf{C}\,\mathbf{i}_{new}$):—

$$\mathbf{C} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc|cccccc} 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 \end{array} \\ \left[\begin{array}{cccc|cccccc} 1 & & & & 1 & 1 & & & & \\ & 1 & & & & & 1 & & & \\ & & 1 & & & & & 1 & 1 & \\ & & & 1 & & & & & & 1 \end{array}\right] \end{array}$$

The formula $\mathbf{C}_t\,\mathbf{Z}\,\mathbf{C}$ establishes the resultant 32 × 32 **Z** matrix of Fig. 7*b*. (Since the CPC could not perform the doubling or trebling of some of the rows and columns of the 16 × 16 **Z** matrix, the work was performed with the aid of scissors and scotch tape.)

The second step consists of adding the actual tie-line impedances Z to the respective tie-lines (Fig. 6*c*). This is performed by merely adding the appropriate scalar Z to each diagonal element of the augmented matrix along the added axes only.

The second step in re-establishing the boundary impedances may be further simplified by performing it only after all the subdivisions have been interconnected. In that case the boundary impedances need not be cut into two parts, but are added to the **Z** of the interconnected system. One single $\mathbf{Z}_\infty$ is added to each diagonal element. Familiarity with the analysis of electrical networks suggests a long succession of such labour-saving tricks as the size of the networks increases.

Acknowledgements.—This project is part of the general programme of the Nuclear Engineering Unit of the Knolls Atomic Power Laboratory, supervised by Harry E. Stevens, Jr. Acknowledgement is due to Mary Ann Havill for her assistance and to Sarah G. Fleming for her supervision.

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HIGH-SPEED TOOLROOM LATHE

Rigid Design for Heavy Cuts

The Hardinge H.L.V. lathe, which has been introduced by Hardinge Machine Tools, Limited, Feltham, Middlesex, has been designed for rapid production of short runs of components with a high degree of accuracy. It has a maximum swing of 11 in. over the bed and 9 in. over the saddle, and will accommodate work 18 in. long between centres when the tailstock is flush. With the tailstock overhung the maximum length of work which the lathe will accept is 20 in.

The lathe is carried on a fabricated steel cabinet base, which houses the driving motor and variable-speed drive gear. Adequate ventilation for the drive unit is provided by an expanded-metal panel in the rear of the cabinet. The base also contains a tool-storage compartment, with a collet board, and incorporates a chip-tray and coolant sump. The motor is of the two-speed, reversing type, with a push-button starter, and drives the spindle through a variable-speed gear giving a steplessly-variable range of speeds from 125 to 3,000 r.p.m. Lever-operated controls are provided at the front of the machine.

The headstock spindle is mounted in pre-loaded ball bearings and has a 1¼-in. diameter hole through it to pass stock and the collet draw-spindle. The nose is bored for a Hardinge 5C collet, which will take 1-in. diameter rounds, ⅞-in. hexagons, and ¾-in. squares. In addition to a range of collets, the spindle will accommodate step-chucks, jaw-chucks and a faceplate.

The saddle, which has a compound slide-rest, is carried on a flat bed of hardened and ground steel of dovetail form, on which the headstock and tailstock are also mounted. The under-cut V-guides of the bed and large bearing surfaces of the three component assemblies ensure maximum rigidity. The compound rest, which takes a tool ⅝ in. by 1 in., has a travel of 3 in.

Longitudinal and cross-traverse are independent of the lead-screw, an infinitely-variable electric drive being provided to give power feeds of from ¼ in. to 7 in. per minute. Finger-tip snap-up clutches are provided on both the longitudinal and cross traverses, and speed control is effected by a hand-wheel and graduated scale at the right-hand end of the lathe bed. The rate of feed can be changed at any time, when the lathe is at work and under load, by turning the control knob. The hand-control wheels on the saddle are fitted with large graduated collars, with friction mountings for zero-setting, and marked with black figures on a white ground.

For screw-cutting the lathe is equipped with a 1-in. diameter lead-screw, with eight threads per inch, carried in pre-loaded ball bearings. An automatic lead-screw stop, with adjustable collars, is provided. The quick-change gearbox gives a range of 27 different threads, from 11 to 80 per inch, which covers all the standard English systems, including pipe threads.

The tailstock spindle, which is 1⅜ in. in diameter, and has a travel of 3¾ in., is bored to No. 2 Morse taper. A drill chuck for the tailstock is among the extra equipment which can be supplied. This additional equipment also includes a taper-turning attachment, steady rest, collets, chucks, faceplate, lever-operated collet closer, and radius-turning attachment. Coolant-supply equipment can also be provided as an extra feature, and when required, an automatic-indexing square turret can be fitted to the compound rest.

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TRACING RIVER-BED MOVEMENTS

Use of Radioactive Isotopes

Radioactive ground glass has been injected into the Thames at Gravesend to see if it is possible to trace the movements of the mud on the river bed. For some time it has been suspected that the dredged mud from the river channel and London dock areas, most of which is dumped at sea beyond the estuary, is being carried back up the river again by the tide. To determine what, if any, movements are occurring, glass impregnated with radioactive scandium oxide has been injected into the mud; before being used, the impregnated glass was irradiated in the atomic pile at Harwell to form the isotope scandium 46. Ground glass was selected as the vehicle for the isotope because its particle size could be made similar to that of the mud when its waterborne behaviour would also be similar.

After injection into the river the radioactive glass is sought using an underwater Geiger counter. Preliminary experiments have shown that a few tidal cycles are sufficient to move the particles two or three miles upstream; after five days some had moved as much as 16 miles. Large-scale experiments are now to be put in hand so that more conclusive results can be obtained. The investigation is being conducted by the Hydraulics Research Station of the Department of Scientific and Industrial Research.

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In an article on page 185 of the issue of February 11, 1955, entitled "Overcoming Frequency Variations," a sentence in the last paragraph should read: "The set compensates for an input frequency change of up to one cycle per second *per minute* with a 50-cycle supply," and not as stated.

The Hardinge H.L.V. lathe has a hardened steel dovetail bed, and infinitely-variable speed longitudinal and cross-traverse independent of the lead-screw.

"DEUCE"

A COMPUTER FOR SOLVING COMPLEX PROBLEMS AT HIGH SPEED

For some years now the English Electric Company, Limited, have been using electronic calculating machines for solving the many problems that arise in the design and development of the wide range of products for which they are responsible and have thus been in a position to appreciate the enormous saving of time and effort that can be effected by their use. Work with these machines has been carried out in the Nelson Research Laboratories, at Stafford, which provide an extensive computing service for the whole of the English Electric organisation, and also for their customers. The earliest calculating machine to be used there was an alternating-current network analyser installed in 1949 (ENGINEERING, vol. 169, page 38, 1950), and employed since then on the solution of power-system problems both for their own work and for power-supply organisations in many parts of the world. A second machine, which is of the electronic analogue type, was produced in prototype form shortly afterwards and has been employed for the analytical solution of automatic-control problems. From this prototype a machine was designed and constructed in the Nelson Laboratories for the firm's aircraft division at Warton Aerodrome, near Preston, and has been used there in the design of the Canberra aircraft and more recently of the P1 fighter.

ORIGIN AND DEVELOPMENT

The machine with which we are now concerned is the Digital Electronic Universal Calculating Engine, known as the DEUCE, from the initial letters of its full name, and this machine was demonstrated to a large number of the company's guests in the Nelson Research Laboratories on Thursday, February 17. It is the outcome of ideas originated at the National Physical Laboratory, Teddington, shortly after the war. At that time, the Director of the Laboratory, Sir Charles Darwin, approached Sir George Nelson with the request that his company should assist the mathematical staff of the N.P.L. in the development of an Automatic Computing Engine the logical design of which had already been worked out at Teddington. As a result of this co-operation a Pilot Model ACE was brought into operation in the Mathematics Division of the N.P.L. in February, 1952, and since then this machine has been used with great success in solving problems for many branches of the Government and industry. The DEUCE is a new version of this Pilot Model embodying all the improvements suggested by the operational experience gained at Teddington. Three of the machines were shown at the demonstration, and of these one is for the National Physical Laboratory, one for the Royal Aircraft Establishment, Farnborough, and one will be retained for use in the Nelson Research Laboratories. Later, another similar machine is to be set up in the company's London offices.

GENERAL PRINCIPLES

In common with all high-speed digital computers the DEUCE is capable of carrying out sequences of elementary arithmetical operations, such as addition, subtraction, multiplication and division, together with some logical operations, the most important of which is the ability to proceed along either one of two alternative paths at specified points in the calculation, depending on the results obtained up to those points. To do this the machine must be supplied with a "programme of instructions" which it is to carry out, this programme being coded into numerical form and fed into the storage system of the machine together with the required numerical data. All operations within the machine are carried out in the binary arithmetical scale, the numbers and instructions being represented by sequences of pulses at intervals of 1 microsecond. A train of 32 pulses, known as a "word," is used to represent either a number (equivalent to 9 decimal digits with sign) or an instruction.

Two methods of storage are employed in the DEUCE. One of these is associated with the computing circuits and includes 12 mercury delay lines each storing 32 words, together with 10 shorter lines used as accumulating registers, etc. Both types are illustrated in Fig. 1. The other store is in the form of a magnetic recording drum and is of large capacity; it is shown in Fig. 3. On it 8,192 words can be stored. Information can be written on or read from 256 tracks on the circumference of the drum by means of two sets of 16 heads either of which can be shifted longitudinally into 16 positions so that any head of the appropriate set can record on, or read from, any one of the 256 tracks. The shifting mechanism gives access to any track in 25 milli-seconds which is slow in comparison with the speed of operation of the computing circuits. This, however, is of no consequence because the transfer operations are required infrequently and useful work can be carried out while they are in progress.

Each instruction word specifies some transfer within the machine and thus determines the source from which a number is to be extracted and the destination to which it is to be sent. To achieve maximum speed, optimum coding is used: i.e., each instruction also specifies the timing and duration of the current transfer and the position in the store from which the next instruction is to be taken. This system avoids the loss of time which would otherwise occur if instructions were placed consecutively in the store causing the computer to halt after each operation until its next instruction is emerging from the mercury line in which it is stored. It is thus possible to perform all the elementary operations in 64 microseconds; the only exceptions are multiplication and division, which require two milliseconds. During this time, however, all other facilities in the machine are available for the performance of other operations simultaneously with the multiplication or division.

INPUT AND OUTPUT OF INFORMATION

The input and output of information to and from the machine is by punched cards of standard type. Each input card can carry 12 instructions or up to 32 decimal digits. The latter can consist of three nine-digit numbers (each with a sign) or several smaller numbers. Information can also be supplied in sterling or other non-decimal form if required; the computer converts the numbers to binary form and sends them to its storage system. The cards are read at a maximum speed of 200 per minute. The reverse process is carried out at the output end, the speed in this case being 100 cards per minute, corresponding to about 50 decimal digits per second. The computer has been designed so that in special circumstances punched paper tape, or magnetic tape, can be used instead of, or in conjunction with, standard punched cards for the input and output.

GENERAL ARRANGEMENT

A good idea of the physical form of the DEUCE can be obtained from Fig. 4, which shows the control desk in the centre with the input unit on the left and the output unit on the right. The main electronic units and the magnetic store are housed in nine vertical cubicles each containing about eight chassis and these, together with the control desk, occupy a floor area of 14 ft. by 4 ft. 6 in. Access to the components is obtained through doors on one side of the chassis and the valves, all of which are on the inward-facing side of each chassis, are reached through a central corridor. About 1,300 valves are used, all of which are of standard miniature types universally available. The mercury delay lines, with the exception of those of short length for one, two or four words, are contained in a drum 3 ft. in diameter and 3 ft. 6 in. in height which is located at a convenient distance from the electronic units. The temperature in this drum, which is illustrated in Fig. 2, is thermostatically controlled. A power unit, supplied from the mains, provides all the current required by the computer. The power unit is operated remotely from the control desk and can be located at any convenient distance from the machine. The consumption is about 7 kW and provision is made for connection to a forced-ventilation system in order to remove heat and thus prevent the room temperature from rising unduly.

The question of reliability has naturally been given most careful consideration in order to avoid failures while a computation is in progress. Sudden failures of valves or other components are, of course, unpredictable but they usually occur when switching on or off, so that interruption of useful work from this cause is quite infrequent. The most difficult type of fault to deal with arises from slow variations in the values of components. To detect these before their effects become harmful, marginal checking circuits are incorporated in the DEUCE. A series of test programmes is provided which test the operation of each part of the machine in turn. In the event of a fault the result obtained indicates its nature and it can then be located by application of the marginal checking facilities to particular elements of the suspected group of circuits. Most faults can be located and repaired in a few minutes, so that it is unnecessary to provide spare units or the extensive special test gear which would be required to check them under operating conditions.

PROGRAMMING OF INSTRUCTIONS

As previously mentioned, the solution of problems on a digital machine requires initially

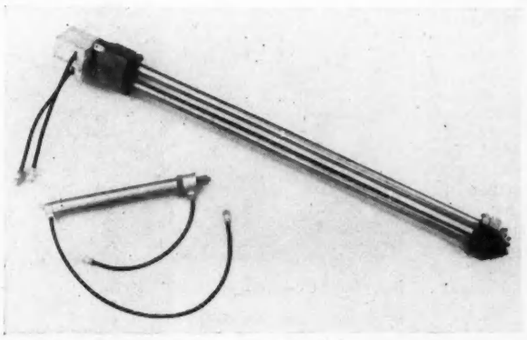


Fig. 1 Long and short mercury delay lines which store data until required.

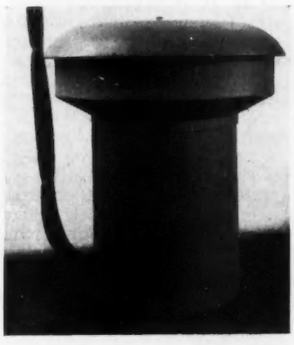


Fig. 2 Temperature-controlled enclosure for long delay lines.

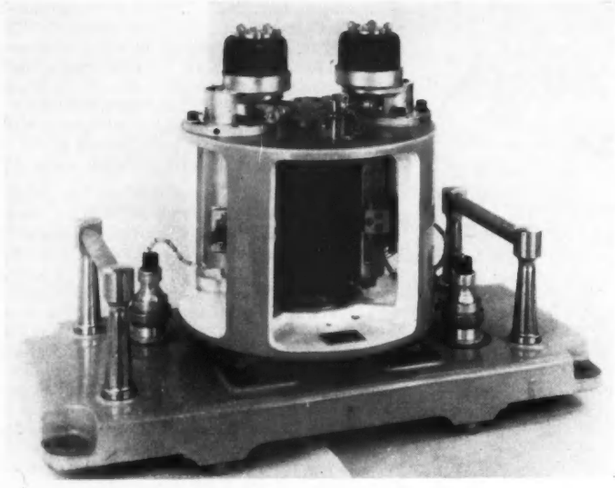


Fig. 3 Magnetic drum capable of storing 8,192 "words."

the production of a programme of instructions for those particular problems. To assist in the preparation of these programmes extensive test facilities have been provided so that once a correct programme has been produced it can be used indefinitely with the various forms and values for the data of the particular problem. One of the special features incorporated in the DEUCE can be used to cause the programme to be carried out in steps at the rate of 20 steps per second. With this, the output punch is used to punch out each instruction as it is executed instead of punching out the results. Comparison of the output cards with the intended sequence of operations will then indicate the points of failure of the programme. This method effects a considerable saving in machine time in comparison with the usual method of proceeding step by step under manual control and observing the progress of the calculations on a monitor showing the contents of storage locations. Monitoring facilities, however, are provided to enable the contents of any storage location to be examined for use in certain aspects of programme and machine testing.

To facilitate the preparation of programmes of instruction, a library of "sub-routines," applicable to all DEUCE machines, has been prepared by the combined efforts of the National Physical Laboratory, the Royal Aircraft Establishment and the English Electric Company. This library, which is organised by the company, already includes most of the sub-routines in general use, and will grow continuously as the use of the machine extends; it will be available to all users.

MATHEMATICAL WORK CARRIED OUT

Having now indicated the manner in which the machine functions we may give some idea of the work for which it is suitable and of the time saving effected by its use. As our readers will be aware, many problems in engineering reduce to the solution of large sets of linear algebraic simultaneous equations. It would be impossible to solve a set of 60 such equations by conventional methods of computation but it could be solved on the DEUCE machine in a total time of 18 minutes which includes the input of information and the output of the solutions on punched cards. The largest set of simultaneous equations ever solved on the machine was one of 115 equations with 37 right-hand sides. Other problems of frequent occurrence involve the solution of sets of linear differential equations. A set of 60 such equations requires six minutes for the input of the coefficients, two minutes for each step of a Runge-Kutta process and one minute for the output of results at any step. Results are not usually required after every step; in many cases they are only needed after every fifth or tenth step. One other class of engineering problem which may be mentioned requires the determination of the largest latent root of a high-order matrix. This is usually carried out by an iteration process and the time required to obtain the root depends upon the number of iterations which have to be made to obtain the accuracy necessary for the particular problem. The time may, however, be estimated from the fact that the input of the coefficients for a matrix of order 60 occupies six minutes and each iteration takes one minute

ASSISTANCE TO INDUSTRY

These and other mathematical techniques have been extensively employed with the electronic computer in solving problems that have arisen in the work of the English Electric Company and their associates. In addition to the problems of aircraft design, both structural and aerodynamic, the light-current engineering work of the Marconi Company gives rise to many problems in electron optics and wave-filter design which the machine has been able to solve rapidly. The heavy engineering work of the parent company also calls for the solution of many complex problems such, for example, as the calculation of the oscillations in the surge tanks of hydro-electric power stations and the critical speeds of multi-span shafts for large turbo-alternators. The design of guided missiles also involves much mathematical work for which the electronic computer can be employed. These examples of the application of the computer, which are by no means exhaustive, serve to illustrate its versatility and suggest that it is likely to play a part of increasing importance in the future progress of the engineering industry.

A SIMPLE PROBLEM

As an addendum to the above account of the machine, we may give some extracts from a film exhibited during the demonstration referred to above, showing the operations involved in solving a very simple problem. These extracts, with the accompanying diagrams, may enable the action of the machine and its main components to be followed more easily. Fig. 5 shows the input arrangements diagrammatically. The input card, with rows of punched holes representing numbers on the binary scale, is moved upwards and as it does so brushes, represented by arrows on the diagram, make contact through the holes with a roller and thus the appropriate valves are energised. Pulses in a regular sequence are fed from the left and those which pass through the energised valves leave from the right as a series of appropriately-spaced pulses representing, in this case, the number 43. These and subsequent pulses are passed through a gating valve into a mercury delay tube in which they are stored until required for use.

One of these tubes is illustrated diagrammatically in Fig. 6. The electrical pulses entering one end of the tube are transformed there by a piezo-electric crystal into pulses of acoustic waves of ultrasonic frequency which are represented in the diagram by dark circles. After traversing the tube and reaching the distant end they are transformed into electrical pulses by another crystal, amplified, returned to the tube and re-circulated, this action continuing as long as may be necessary. When required for use in the computer, signals are taken from the amplifier when the desired number is being regenerated.

As previously mentioned, these long mercury delay lines will store up to 32 "words." When a larger number of digits and instructions have to be stored, the magnetic drum shown in Fig. 7 is used. The drum, which is coated with a magnetic oxide, rotates at 6,000 r.p.m. and by means of a set of 16 heads on each side of it, the 32 words from one mercury delay tube can be transferred to, or read off from, the drum in a single revolution. The heads can be moved longitudinally into 16 positions thus giving access to 256 tracks on the surface of the drum. Thus $256 \times 32 = 8{,}192$ words can be stored on the magnetic drum. Fig. 7 shows a mercury delay tube on the right and the magnetic drum, with only six heads on each side for simplicity, on the left. In the diagram the third head from the top on the left-hand side is recording information from the mercury tube. One of the set of heads on the right-hand side of the drum would be used for returning information from the drum to a mercury tube.

The diagram, Fig. 8, illustrates an elementary form of this computer arranged for solving a very simple problem involving only addition and multiplication. The problem is $(6 + 5)5 = 55$. The diagram shows the two numbers 6 and 5 stored in the mercury tube on the left and the five operating instructions A, B, C, D, E, stored in an adjacent mercury tube; the numbers and instructions could, however, be stored equally well in a single tube. To the right of the mercury tube containing the instructions is the adding register and on the extreme right is a short delay tube. By the first instruction A the number 6 is transferred from the long delay tube on the

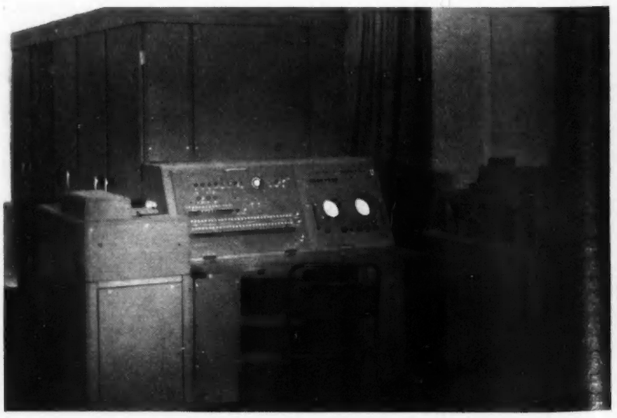


Fig. 4 Control desk with input unit on left and output unit on right.

left to the adding register, and by the next instruction B the pulse train representing the number 5 is transferred to the adding unit, where it is merged with the pulse train representing 6, forming the sum 11, which replaces the original number 6. By the next instruction C the number 5 is transferred to the short delay tube on the right. Instruction D energises the multiplier indicated in the top right-hand corner of the diagram and this then forms the product of the two numbers stored in the adding register and the short temporary register. Multiplication is effected by sampling the successive digits of the number 11 and adding the number 5 when appropriate. The number 11 is destroyed in the process and replaced by the product 55, which is transferred as a series of pulses from the adding register to the output organ.

This is shown diagrammatically in Fig. 9. One of the pulses proceeding from the right is being gated through to set the third punch knife. When all the knives corresponding to the train have been set, the punch operates and presses the knives through the card to form, in this case, the number 55 in binary digits. This completes the operations involved in this simple problem, but when other numbers have to be presented, the card is moved up one row and a second pulse train is reproduced in the second row, and so on. Twelve numbers can be punched on one card.

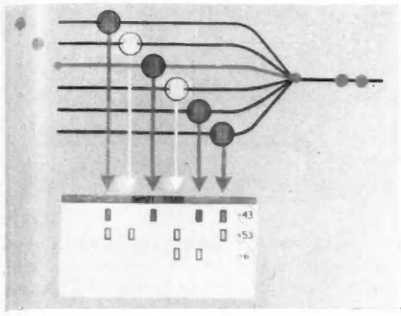


Fig. 5 Input arrangements. Brushes make electrical contact with a roller beneath the perforated card and energise appropriate valves.

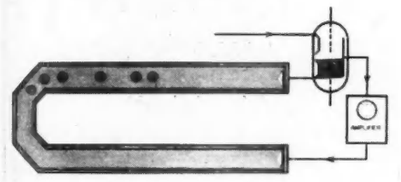


Fig. 6 Mercury-filled delay tube which stores pulses representing numbers until they are required.

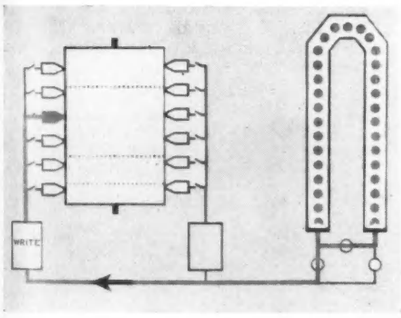


Fig. 7 Magnetic drum capable of holding the contents of 256 mercury delay tubes.

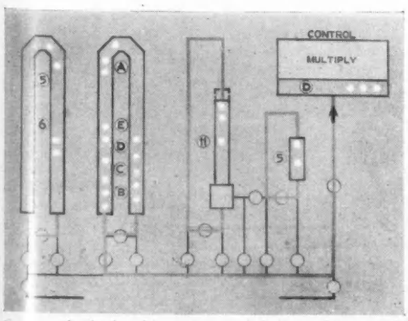


Fig. 8 Elementary form of computer, set for solving a simple problem.

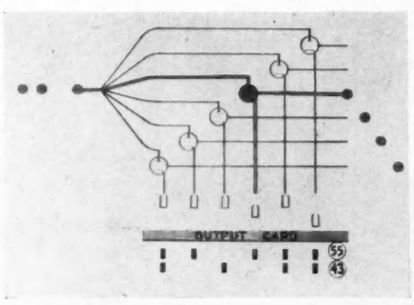


Fig. 9 Pulses supplied from the right cause punches to cut holes in a card which gives the result of a computation.

H.M.S. ARK ROYAL

POST-WAR AIRCRAFT CARRIER DEVELOPMENTS

H.M.S. Ark Royal, the first aircraft carrier to be fitted with all the post-war developments in flight-deck technique, put to sea recently for her acceptance trials with her full commissioning crew under a Master nominated by her constructors, Cammell Laird and Company, Limited, Birkenhead.

With a 5½-deg. angled deck, steam catapults (the first to be fitted on an operational vessel), a new type of arrester gear, the first deck-edge lift to be fitted in a Royal Naval carrier as well as central lifts, mirror deck-landing aids on both port and starboard sides, hangars with improved ventilation, and a special air-crew refreshment centre designed to eliminate delay and crew fatigue, the Ark Royal will be able to fly-off and land-on the heaviest and fastest types of aircraft envisaged in naval warfare, and to handle them more safely and rapidly than any former carrier.

The Ark Royal is 808 ft. 3 in. long overall (720 ft. between perpendiculars) and has an extreme breadth on the waterline of 112 ft. 9 in. Her displacement is 36,800 tons (that of H.M.S. Illustrious is 23,000 tons). Her peace-time complement will be 110 officers and 1,522 ratings. When her front-line aircraft are embarked there will be, in addition, about 100 officers and between 450 and 500 ratings.

The Ark Royal's armament consists of 16 4·5-in. guns and 45 smaller guns. In constructing the hull, electrical welding has been used on a very large scale to provide the lightest and strongest structure possible, but there are many parts of the warship in which riveting was employed.

Cammell Laird are responsible for the main machinery, which consists of a four-shaft arrangement of geared turbines of a type which will give the ship a high speed and ensure that degree of special mobility which is required in an aircraft carrier.

Fuel for the aircraft is to be stored in several groups of tanks dispersed throughout the ship so as to reduce the risk of fire to a minimum. Magazines for storing all types of airborne weapons will be in other protected parts of the ship, from which items such as heavy bombs can be raised by a special lift.

The latest radio and radar equipments are fitted both for the navigation of the ship and for the control and direction of her aircraft and guns in all weathers.

A great deal of attention has been devoted to the photographic needs of the Ark Royal. The scope extends from the reproduction of charts and documents to the photographing of large areas from the air. Photography is used for recording all deck landings, radar traces and instrument readings, and in association with, or even as an integral part of modern weapons. The Ark Royal's photographic section is considerably smaller than a laboratory ashore, but is capable of dealing with a large variety of demands. A universal processing machine, occupying only 12 ft. by 2½ ft. of deck space, can develop and dry all widths of film in use in the Service from 16 mm. to 9½ in. wide. The process can be carried out at a speed as fast as 1,200 ft. per hour. Vibration-free enlargers can operate with the ship travelling at full speed and in any kind of sea. With the large stocks of photographic material carried in refrigerated compartments, the Ark Royal may serve as a central processing laboratory for other ships in a striking force.

In order to meet the large demands for electrical power, a generator capacity of 4,000 kW is provided. There are four steam-turbine and four Diesel-driven sets, each rated at 500 kW and dispersed throughout the ship to minimise the effects of action damage. A 220-volt direct-current ring-main system, incorporating approximately 350 electrically-operated circuit-breakers, is used for distributing electrical power. Control of the supply and distribution systems is effected from a large main switchboard or, in an emergency, from four smaller switchboards each of which controls a quarter of the aircraft carrier.

Continuity of supply for the vital services of the ship is ensured as far as possible by the duplication of supplies fed through automatic or hand-operated changeover switches. Rapid restoration after failure of both normal and alternative supplies may be carried out by means of an emergency supply system.

Approximately 10,000 lighting points are installed, 3,000 of which are fitted with twin 20-watt fluorescent tubes. Part of this installation consists of red lighting to allow for rapid adaptation of vision at night. In the event of the normal lighting supplies being put out of action following severe damage to the ship, battery-operated emergency lanterns are automatically switched on.

For starting and servicing Naval aircraft, a number of fixed motor-generator sets, with their associated control gear, supply socket outlets on the flight deck and in the hangars. This obviates the need for cumbersome batteries and trolleys.

Since there are about 1,300 compartments in the ship, electrical communications are of great importance. Some 1,500 telephones are installed, 500 as outstations on an automatic exchange and the remainder, mostly sound-powered, as outstations on direct telephone systems.

In addition to the foregoing an integrated main-broadcast system is fitted. General information, warning signals, etc., are passed over this system to all parts of the ship. In action, the various departments of the ship can take control of appropriate units of the system; only warning signals from the main system can override transmissions on the unit system.

PIPE-FLANGE MACHINING AND RADIAL DRILLING

New Kitchen and Wade Machines

Two new machine tools, one a pipe-flange facing machine and the other a portable radial driller, have been introduced by Kitchen and Wade, Limited, Arundel-street, Halifax. The two machines are shown in the illustrations at the foot of the page.

PIPE-FLANGE MACHINING

The pipe-flange facing machine is of the double-head type, the facing heads being carried on columns which can be adjusted along the machine bed to suit pipes of any length up to a maximum of 14 ft. The two heads, which have 2 ft. 9 in. of vertical adjustment, are of right-hand and left-hand construction, but are otherwise identical. Each is driven by a 5-h.p. electric motor through a gearbox giving six speeds in three ranges: 50 to 15 r.p.m.; 90 to 15 r.p.m.; and 88 to 25 r.p.m. The heads have two feeds, one forward and one reverse, and cuts can be taken outwards and inwards, the facing head returning to its starting position. The gears and bearings in the heads are pressure-lubricated, and column and saddle-locks are provided. Each head can be operated indpendently of the other.

Two 3-ft. by 3-ft. squaring-tables are provided on the machine bed, each one having cross and longitudinal adjustments. The tables have power feeds of $\frac{1}{2}$ in., 1 in., and $1\frac{1}{2}$ in. per minute, and there is also a rapid traverse of 10 ft. per minute. Rotation of the tables is provided for, with positive indexing at 90-deg. intervals, and there are four clamps for locking. A jacking device is provided in the tables to break the joint for easy rotation. Safety trips are fitted to all the power traverse motions.

RADIAL DRILLING MACHINE

The 7-ft. portable radial drilling machine has four wheels on the bed for short-distance movement and a lifting shackle on the top of the column for use with a crane. The drilling head is fully enclosed and has a double swivel mounting to enable holes to be drilled at any angle. The spindle is bored to No. 4 or No. 5 Morse taper, and has 18 in. of traverse. There are three power feeds and fine and quick hand-traverse motions. The drive, which is enclosed, is from a 5-h.p. electric motor, mounted at the rear of the arm on the column, and driving through a gearbox which gives 12 spindle speeds from 500 to 20 r.p.m. The column is mounted on a slide, with ball-bearing rollers for easy movement. Outrigger supports, with screw-jack feet, are incorporated in the bed. The maximum distance from spindle to floor when the spindle is in the vertical position is 7 ft. 6 in. The machine will drill a hole in the horizontal plane 10 ft. from the floor. It weighs 7 tons 15 cwt. and has been designed for lifting into place by crane.

* * *

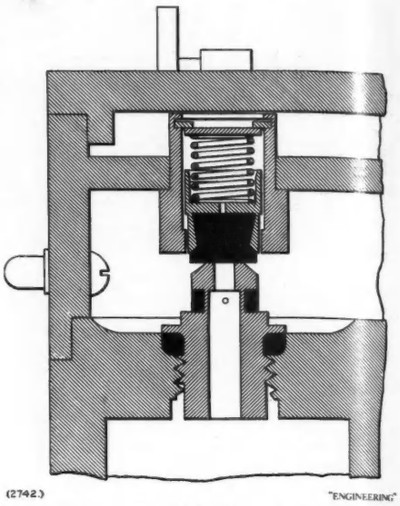
STOPPER FOR ACCUMULATORS

Leakage of Electrolyte Prevented but Gas Escape Permitted

One of the problems encountered with "wet" batteries is that of preventing leakage of electrolyte when the battery is tilted or inverted, while yet allowing the escape of gas formed during discharge. This trouble is of particular consequence in the cap lamps used by miners. Various types of rubber diaphragms, arranged to release gas when the pressure exceeded 8 lb. per square inch have been used in the past, but have proved unsatisfactory, mainly owing to the fact that they were not stable enough to operate regularly at the given pressure. Nylon stoppers have also been tried.

A design has, however, now been produced by Mr. T. M. Muirhead, chief electrical engineer of No. 3 Area of the North Eastern Division of the National Coal Board, and has proved satisfactory during official trials held between May and July, 1954. Twenty-five lamps were fitted with these seals and, during the trial period, there was no evidence of leakage. The lamps are still in use and giving good service. A drawing of the stopper is given above. One is required for each cell of the battery.

A steel stopper screws into the top of each cell and has its outer end sealed by a spring-loaded rubber cap. This allows for any variation in dimensions and the seal is made automatically when the cover of the battery is closed. In this way the battery can be kept at atmospheric pressure during charging by removing the cover. A circlip holds the spring in place. Emergency release of gas in the cell occurs through radial holes in the stopper which are sealed with a rubber ring. This lifts at 20 lb. per square inch, and is considered to be capable of about 8 months' service. It is claimed to be the only part requiring renewal.



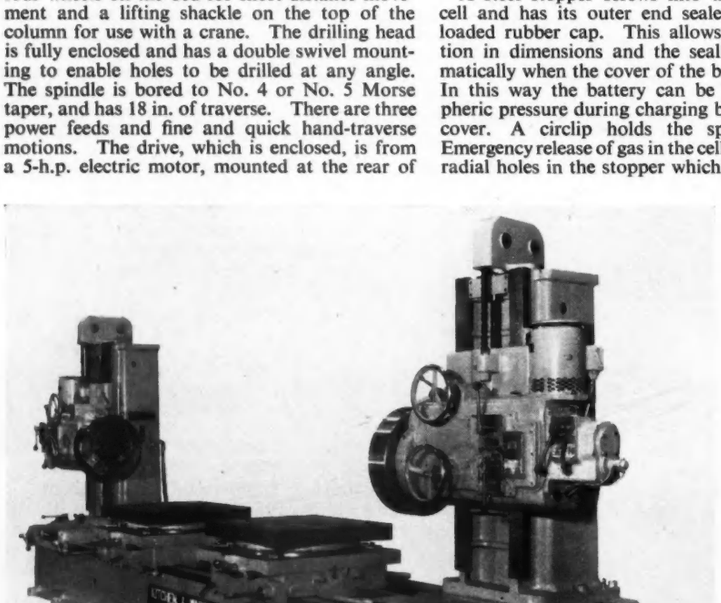
Closing the cover of the battery presses the rubber cap against the stopper and seals the cells. Gas can escape through the radial holes normally closed by the rubber ring.

* * *

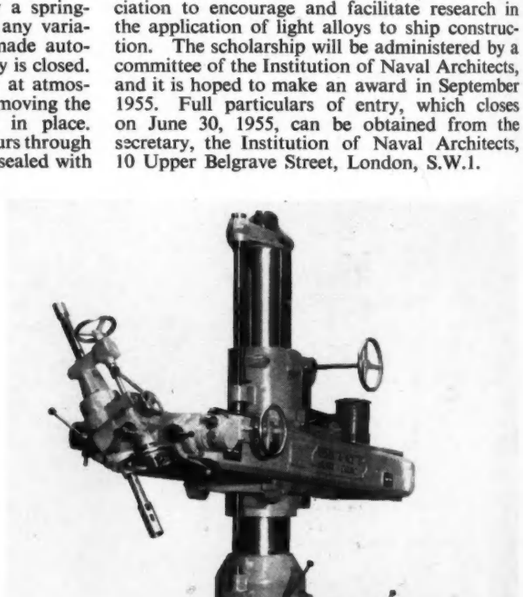
LIGHT ALLOYS IN SHIP CONSTRUCTION

£400 Scholarship

A research scholarship of the value of £400 per annum and tenable for two years has been offered by the Aluminium Development Association to encourage and facilitate research in the application of light alloys to ship construction. The scholarship will be administered by a committee of the Institution of Naval Architects, and it is hoped to make an award in September 1955. Full particulars of entry, which closes on June 30, 1955, can be obtained from the secretary, the Institution of Naval Architects, 10 Upper Belgrave Street, London, S.W.1.



The Kitchen and Wade pipe-flange facing machine will take pipes up to 14 ft. long. The two facing heads are independent and there are two squaring tables each having cross and longitudinal adjustments.



The K. and W. portable radial drilling machine is designed for lifting into place by a crane. The drilling head is mounted on a double swivel, and holes can be drilled at any angle.

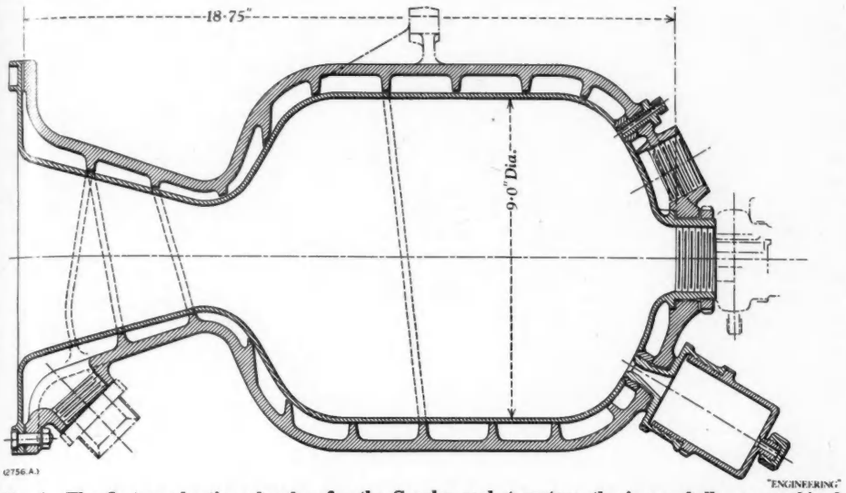


Fig. 1 The first combustion chamber for the Snarler rocket motor; the inner shell was machined from forgings and enclosed in a casing machined from a light-alloy casting.

DEVELOPING A ROCKET MOTOR

LIQUID-OXYGEN AND WATER-METHANOL FUEL FOR AIRCRAFT PROPULSION

In our issue of September 17, 1954 (*vol.* 178, *page* 374), *we published a description of the Armstrong Siddeley liquid-fuel rocket motor, the first British rocket unit to be released completely from security restrictions. Further details of the problems encountered in developing the motor and its flight trials, which took place in* 1950 *in a Hawker* P.1072 *aircraft, have been given recently in a lecture by Mr. D. Hurden before the British Interplanetary Society, entitled "The Development of the Armstrong Siddeley Snarler Rocket Motor." We give below a summary of the main part of the paper in which Mr. Hurden described the engineering and development of the various components; for details of the operation of the motor readers are referred to the earlier article.*

In 1946 Armstrong Siddeley Motors, Limited, were asked to design and make a liquid-propellant rocket motor for boosting the rate of climb of a fighter aircraft. The motor was to be of 2,000-lb. thrust, its propellants were to be kerosene and liquid oxygen, and it was to be capable of being started and stopped in the air.

MACHINED COMBUSTION CHAMBER

To keep the combustion chamber from burning out, the flow of coolant round it had to be closely controlled to maintain a reasonably high scrubbing velocity. It was decided to machine the inner shell fully from forgings and to enclose it within a casing machined from a light-alloy casting. Coolant velocity was to be maintained by a helical passage cast in the casing. Expansion of the inner shell relative to the casing was supposed to be taken up by flexure of the annular diaphragm at the exit end. The first version of the combustion chamber is shown in Fig. 1.

Injector flow tests at first presented some difficulty since no pumps were available in the works able to deliver about 30 gallons a minute at a pressure of 100 lb. per square inch. However, the injectors were put on a portable rig containing pressure gauges and Venturi meters for flow measurement and were supplied with water from a trailer pump by the works fire brigade. The spray from this first injector was quite hollow. It was thought that if only one injector was to be used it should give a mixture of fuel and oxygen uniformly distributed across the chamber. Accordingly several more models were made and flow-tested. Patternation tests were carried out as well as calibrations.

The injector finally decided upon is shown in Fig. 2. Oxygen was sprayed from the inner ring of jets and fuel from the outer. The oxygen jets and fuel jets impinged on one another, the oxygen jets all being drilled at the same inclination while the fuel jets were drilled at three different angles to give a wider distribution of the spray. With minor modifications, injectors of this type were used in the flight engine.

IGNITION TESTS

For ignition tests, a crude water-cooled combustion chamber was fabricated from sheet metal. The injector and igniter were in the same relative positions as they would occupy in the proper combustion chamber. The correct igniter had not been made, so these tests (and the early firings) used electrically-fired solid propellant charges lasting about 5 seconds for ignition. Fuel and oxygen were fed to the chamber from pressurised tanks through German valves. The timing of the igniter and the opening of the valves were controlled by a bomb-release switch, and the firing of the igniter and the arrival of propellants at the injector were indicated by crude but effective electrical apparatus. Ignition was signalled to the same apparatus by burning out a wire stretched across the end of the chamber.

A rocket test bed was by now under construction but was not yet ready for use, so these ignition experiments were performed in a sand-bagged emplacement. The controls were operated from a portable switchboard a safe distance away and the tests were observed in a mirror. The first two attempts resulted in ignition with loud reports. At this stage Armstrong Siddeley were advised by the Royal Aircraft Establishment to abandon kerosene as fuel owing to severe cooling problems and to use instead a mixture of 65 per cent. methyl alcohol and 35 per cent. water. The rest of the ignition experiments were completed with this fuel and it was found that the chosen disposition of injector and igniter gave smooth ignition without very critical timing of the propellant injection.

The first firing was successfully completed in November, 1947. The chamber was water-cooled and the starting sequence was again controlled by a bomb switch. Six firings were completed, during which the temperature rise of the cooling water was measured and the flow reduced until it equalled the fuel flow. In March, 1948, the change was made successfully to regenerative cooling by the fuel. Very little trouble was encountered with this combustion chamber, and its basic features were retained in the chamber for the flight engine. The most outstanding difference between the two chambers lay in the casing which had been lightened considerably, while provision for expansion of the inner shell was made by a sliding joint at the rear end.

There remained, however, the problem of relighting in the air. The method was to use a small pilot combustion chamber fed with fuel and oxygen which was to be ignited by a sparking plug. Tests continued off and on for nearly three years. Fig. 4 illustrates the progress of the development of this component. At first it was just a scaled-down version of the combustion chamber turned from hexagonal steel bar and uncooled. This was transformed into a so-called air-cooled igniter with fins turned on its body which gave good service on the test-bed for some time. In due course, however, its nozzle began to erode and the design was complicated by providing a double-walled nozzle cooled with fuel which was then injected straight into the combustion chamber. This improved matters for a time, but inevitably an occasional hot spot was noticed on the finned body and the final step was taken of re-designing it and, copying the main chamber, jacketing its entire length and cooling it with fuel. From the beginning, the fuel and oxygen were injected from two jets which impinged on one another, and although other schemes were tried this method persisted.

BEARING FAILURES IN LIQUID-OXYGEN PUMP

Meanwhile development of the pumps was proceeding independently. In the original paraffin pump the impeller was designed to rotate at 14,000 r.p.m. and had five straight vanes integral with crude inlet guide vanes—a rather unorthodox design. An orthodox shrouded impeller would have been very difficult to cast accurately and the passages quite impossible to machine. This pump underwent only one re-design of any consequence, mainly to increase its capacity so that it could pump methyl alcohol instead of kerosene.

The liquid-oxygen pump was the most difficult part of the engine to develop. The pump as first made had, like the fuel pump, a straight-bladed impeller, but its seals and bearings were

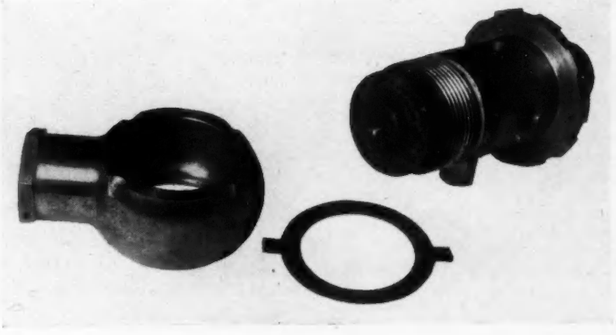


Fig. 2 In the fuel injector, oxygen was sprayed from the inner ring of jets and fuel from the outer. The latter jets were at three different angles to give a wide distribution of spray.

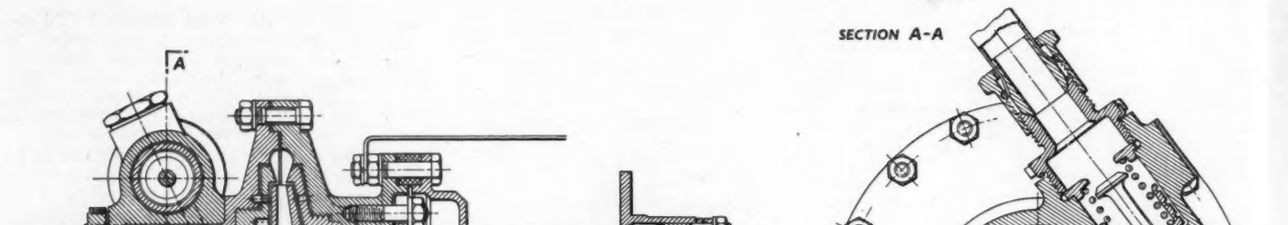


Fig. 3 The liquid-oxygen pump finally evolved; considerable bearing trouble had been encountered during development.

quite different. Carbon face seals mounted on metallic bellows were first tried, while the bearings consisted simply of oil-impregnated bronze bushes. During preliminary tests on water these bearings repeatedly seized, and it was thought to be worth making a rig on which different types of bearings could be tried under actual working conditions. The impeller was replaced by a lump of metal of the same weight, the correct seal was fitted, and low-temperature conditions were reproduced by circulating liquid nitrogen through the casing. Various types of bronze and carbon bearings were tried on this rig without much success and an asbestos-based plastic material caused one of the more spectacular explosions during development. The rig in this case was fed with liquid oxygen, and the heat generated by one of the bearings in the presence of oxygen caused its ignition and subsequent disappearance, together with part of the shaft. [A photograph of the results of this incident was reproduced in the article referred to above.—ED.E.]

As a result of experiments with the bearing rig, the pump was re-designed with ball bearings instead of plain bushes, and was then set to pump oxygen, whereupon the blades promptly broke off the impeller. Another pump was therefore made using the comparatively successful bearings and seal from its predecessor, but employing a shrouded impeller taken from a German pump running in the modified casing of one of the pumps from a Walter motor. This survived long enough to pump some oxygen, thereby giving some encouragement, but suffered from other troubles. Its capacity was low, both in flow and pressure, it was difficult to get it primed with liquid, the seal rapidly became scored, and the rear bearing caught fire. This last was apparently caused by leakage of oil from the gearbox mixed with oxygen leaking past the damaged seal.

Another version of this pump was produced in which the capacity had been increased by enlarging the impeller inlet and adding a booster stage. The face seal was replaced by a spring-loaded leather gland and the fire risk was greatly reduced by interposing a shaft fitted with oil slinger discs between the pump and gearbox. It was the first pump to be used to feed the rocket and although its capacity limited the thrust to 1,300 lb. its use represented an important step in the development of the motor.

Guided by the success of this experimental pump an entirely new pump was designed and built. It was to teach one more important lesson. The impeller and casing were made of light alloy, and during one test a bearing failure occurred which allowed the impeller to foul the casing. A violent explosion promptly occurred as the aluminium powder was ignited by the heat generated by friction, and the front of the pump disappeared down the test cell. [The remains of the pump were illustrated in the article referred to above.—ED.E.] In addition to this serious weakness the bearings had an unacceptably short life, and in the next design the two ball races were replaced by a heavy double-row ball-bearing next to the impeller and a roller race at the other end.

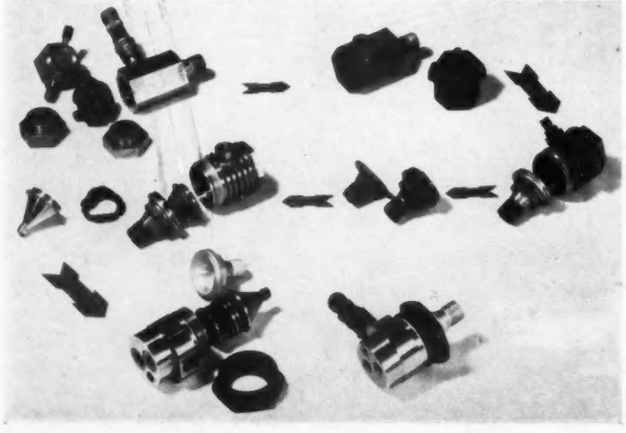


Fig. 4 The progress of development of the pilot combustion chamber.

In addition to this change in mechanical design, the impeller was cast in bronze instead of light alloy and the casing was lined with stainless steel. An earlier test, during which a bronze impeller had rubbed against a stainless-steel face in liquid oxygen for several minutes, had demonstrated the practicability of this combination of materials. Throughout the development of the liquid-oxygen pump various schemes had been tried to eliminate vapour formed in cooling the pump and its associated pipes so that the pump would be full of liquid at starting. The new design incorporated a vapour bleed valve through which, when the pump was stationary, vapour was bled from the highest point in the casing back to the tank. When the pump started and began to deliver oxygen under pressure, pressure was fed from the delivery side of the pump to a piston in the valve causing it to shut.

In spite of the heavier bearing, failures still occurred and it became apparent that unlubricated ball bearings running at 14,000 r.p.m. were not going to be able to carry the loads demanded of them. A final re-design therefore took place, as shown in Fig. 3; the bearings were reversed and the heavy double-row ball bearing—which carried most of the load—was put at the gearbox end of the shaft. Moreover oil seals were fitted between the bearing and the oxygen seal, so this heavily-loaded bearing was now lubricated from the gearbox. The same elaborate arrangements for separating oxygen and oil still existed. The life of this pump was now governed by the life of the roller race near the impeller. It was made of stainless steel and although it was unlubricated it enabled the pump to be run for a few hours instead of a few minutes. In this form the pump was used for the Snarler.

The gearbox assembly for driving the pumps was a fairly straightforward development job. It had to fulfil two functions; first, to divide the drive from the Nene engine into two parts for the two pumps and to step up the speed from 5,000 to 14,000 r.p.m., and second, to provide a means of clutching the pumps in and out so that they were not running all the time the Nene was running. The drive was taken through a simple epicyclic train arranged so that application of a band brake to the outside caused the pumps to be driven. The band brake was applied by means of a piston fed with compressed air from the rocket control system. The most serious trouble with this gearbox remained hidden until the Special Category Test was attempted, whereupon the bronze bushes on which the planet gears ran seized time after time. Two or three weeks intensive work resulted in a

change in the design of these bushes which completely cured the fault, and no other troubles worth mentioning were encountered.

AIR-OPERATED CONTROL VALVES

All the liquid control valves were operated by compressed air acting on a piston. This is common practice in rocket engineering; valves situated in awkward places can be operated easily, positively, and precisely timed. The general design of the valves was the same for fuel as for oxygen, the differences being in the stem and piston seals. For the oxygen valve seals, all kinds of synthetic rubber grew brittle and useless at temperatures below − 40 deg. C., but it was found that water-dressed leather remained fairly flexible down to − 180 deg. C., while treating it with beeswax improved its properties as a seal material. Seals were made of this material in a variety of different shapes and eventually wedge-section rings were chosen as being easily made and reliable.

At first the stop valve and by-pass valve were joined together, while the throttle valve and igniter valve were separate components. Later, all four valves were combined into one valve block. Each type of valve was given an endurance test before using it on an engine. This was done with the help of a simple mechanism which supplied and counted electrical impulses to a solenoid-operated air valve feeding compressed air to the valve under test, which was piped up to an appropriate supply of fuel or oxygen. Once started, this device automatically operated the valve several thousand times and provided a record of the number of operations.

* * *

DYNAMIC BALANCING ON SITE

Portable Electronic Equipment for use on Installed Plant

It is possible to balance certain component parts of rotating plant in conventional balancing machines but, where masses and speeds are high such as in large turbo-alternator rotors, or where final balance trim is required on assembled apparatus, balancing machines can no longer be used and other apparatus must be employed. For this purpose the British Thomson-Houston Company, Limited, Rugby, have developed an equipment known as the Rotabalance set which is intended primarily for the larger sizes of high-speed turbo-alternators running at about 3,000 r.p.m.

The equipment can be used for investigating vibration generally on completed machinery, particularly where it is desired to discriminate between the effects of unbalance and other sources of vibration. Secondly, it can be used for investigating vibration due to unbalance conditions which occur for various reasons when machinery is set up for test or on site.

Thirdly, the balance of a complete machine may be unsatisfactory although its components may have been satisfactorily balanced separately. For instance, the stiffness of the foundations after final erection may be quite different from the test conditions in the factory. If a single unit of a large turbo-alternator is balanced in the factory at its full speed, it is mounted in bearings and on foundations which may be quite unlike those finally used, because no provision is necessary on test for condensing plant, alternator coolers, etc., below the foundations. For a given balance condition in the factory, this may lead to higher vibration amplitudes after final erection.

The equipment, which is shown in the illustration below, consists of a measuring amplifier, a dynamometer, a reference generator (which is attached to the rotor being balanced) and the pick-up units. It is capable of measuring vibration velocities down to 0·005 in. per second, and vibration amplitude down to 0·00005 in. (peak to peak). It will measure relative phase to an overall accuracy of approximately ± 2 deg. Vibration waveforms can be determined by connecting the voltage output from the measuring amplifier to any convenient portable cathode ray oscilloscope.

Being portable, the equipment is also suitable for the balancing of machinery following repairs and overhauls. A recent case where it was used is that of a 51·5-MW twin-cylinder turbine at Hams Hall A Power Station, Birmingham, of the British Electricity Authority, Midlands Division, installed in 1937 and recently re-bladed on site.

The initial run after re-blading showed the machine to be out-of-balance giving a transverse vibration of 0·009 in., double amplitude, and after balancing runs this was reduced to 0·0025 in. Other vibrations were similarly reduced, and the balancing was completed in a total of six hours showing the speed with which such operations can be completed.

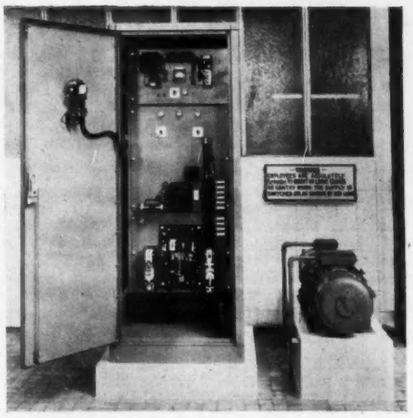
* * *

THE MAGNESTAT VOLTAGE REGULATOR

Automatic Device for Large Alternators

The illustration (above right) shows a Magnestat voltage regulator which has been installed by the British Thomson-Houston Company, Limited, Rugby, on a 30-MW alternator in the Portsmouth power station of the British Electricity Authority. This apparatus has been developed in view of the increasing use of magnetic amplifiers in voltage regulators, and automatically controls the output of the main exciter by adjusting the Amplidyne field and thus maintaining the alternator voltage within the prescribed limits of ± 1 per cent.

A high speed of response is obtained by forcing the Amplidyne and main exciter field currents and by reducing the time constants of the magnetic amplifier and the Amplidyne to a minimum. Another important feature is that the armature voltage of the Amplidyne is reversible, thus enabling the same degree of forcing to be applied, both when increasing and decreasing the excitation.



Magnestat voltage regulator installed on a 30-MW turbo-alternator at Portsmouth power station. The Amplidyne exciter is on the right.

Generally speaking, the Amplidyne exciter can be driven either by a direct-current motor, which is supplied from the constant-voltage pilot exciter, or by a squirrel-cage motor, which is fed from the low-tension alternating-current system. It can therefore be readily applied to both new and existing installations. Positive-phase sequence control and compounding for parallel operation can be provided. The change-over from manual to automatic control and vice-versa can be made smoothly without disturbing the system, and the generator can be returned from automatic to hand control in case of failure. The various controls can be mounted either on the regulator cubicle, as shown in the illustration, or at a distance.

* * *

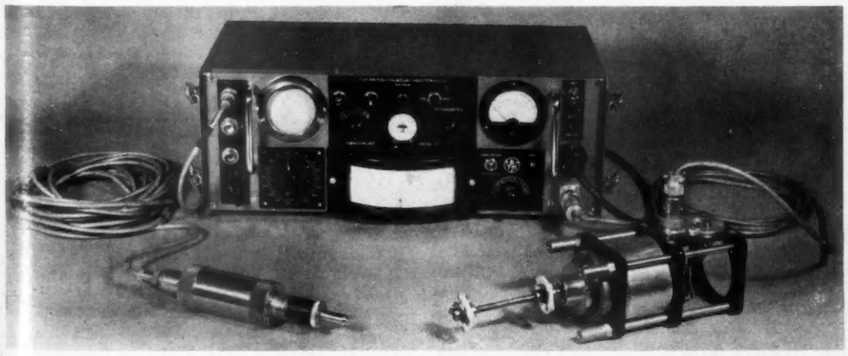
RADIO INTERFERENCE

Compulsory Use of Suppressors

Two sets of regulations, which were laid before Parliament on Tuesday, March 1, give the Postmaster General power to control interference with radio equipment from refrigerators and from the small motors used on domestic and industrial appliances.

The first set, entitled the Wireless Telegraphy (Control of Interference from Refrigerators) Regulation, 1955, prescribes the requirements to be met by manufacturers, assemblers and importers of refrigerators. On the other hand, the second set, entitled Wireless Telegraphy (Control of Interference from Electric Motors) Regulations, 1955, places the responsibility on the user, although the question of applying it to manufacturers will be reviewed during the next two years. The refrigerator regulations will apply to all refrigerators manufactured, assembled or imported after Thursday, September 1, 1955, while the motor regulations, which will come into force on the same date, will apply to both new and old appliances.

It will not be necessary, however, for suppressors to be fitted to motors at once. Only a proportion of the appliances affected cause interference and the Postmaster General hopes that the owners of those that do will put the trouble right when it is pointed out to them. If, however, a suppressor is not fitted voluntarily, compulsion may be used. The Postmaster General also hopes that the practice of certain manufacturers of producing appliances to which a suppressor can be quickly added will be extended.



The component parts of the Rotabalance equipment are the measuring amplifier, the pick-up unit (left) and the reference generator (right).

CONTRACTS

Electronic Equipment. Negotiations with the Hazeltine Electronics Corporation of New York City, acting on behalf of the United States Navy Department, have now been completed whereby contracts for the production of electronic equipment for supply to N.A.T.O. countries have been placed with British electrical firms. The contract received by the BRITISH THOMSON-HOUSTON CO., LTD., Rugby, is valued at 11¼ million dols., that obtained by the GENERAL ELECTRIC CO. LTD., Magnet House, Kingsway, London, W.C.2, is valued at 10½ million dols., and that secured by FERRANTI LTD., Hollinwood, Lancashire, is valued at 4¼ million dols.

Large Turbo-alternator. The British Electricity Authority have ordered a 200-MW turbo-alternator from the ENGLISH ELECTRIC CO. LTD., Kingsway, London, W.C.2. It will be supplied with steam at a pressure of 2,450 lb. per square inch and a temperature of 1,060 deg. F., re-heating to 1,000 deg. F., from a 1,400,000-lb. pulverised fuel-fired boiler, which is to be constructed by INTERNATIONAL COMBUSTION, LIMITED, Woburn-place, London, W.C.1. (Further details regarding this installation are given on page 295.)

Opencast Coal. What is stated to be the largest single contract for working opencast coal ever placed in Great Britain, has been awarded by the Opencast Executive of the National Coal Board to RICHARD COSTAIN LTD., of London. The site lies on the banks of the River Blyth in Northumberland, and further particulars regarding the enterprise will be found on this page.

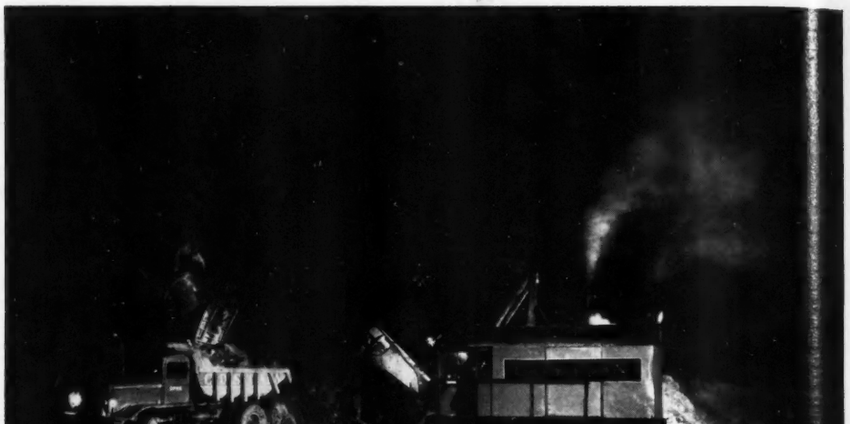
Road Bridge. A contract for the design and construction of a 3,300-ft. long road bridge over the Sone river in the Mirzapur district has been secured by GAMMON (INDIA) LTD., who have their London office at 16 Caxton-street, Westminster. Of prestressed concrete, the spans are of 150 ft. and the foundations are down to a depth of 75 ft. below low-water level. The bridge is to be completed in 15 working months to serve the £9 million Rihand Dam Project.

Water Turbines. A contract for the manufacture and the supervision of the erection of 16 large water turbines, each rated at 75,000 h.p., has been awarded by the Hydro-Electric Power Commission of Ontario to JOHN INGLIS CO., LTD., of Toronto, the Canadian associates of the ENGLISH ELECTRIC CO. LTD., Marconi House, Strand, London, W.C.2. The contract covers the complete turbine installation on the Canadian side of the St. Lawrence great water-power project. The turbines will be built to the designs of English Electric but they will be made in Canada. The guaranteed efficiency of the turbines, when operating under a net head of 81 ft., is 92·5 per cent. The turbine runners will normally operate at 94·7 r.p.m., and have been designed to give a run-away speed of 200 r.p.m. The runner diameter will be 21 ft., and the shaft will be 39 in. in diameter. The spiral casings will be formed in concrete.

Passenger-Carrying Aircraft. A Government order for three Britannia 250LR aircraft for trooping operations enables the BRISTOL AEROPLANE CO. LTD., Filton House, Bristol, and SHORT BROS. AND HARLAND LTD., Belfast, to carry a stage further their joint plans, first disclosed a little over a year ago, for the establishment of a second Britannia production line at Belfast, to supplement the Bristol Co.'s own output from Filton. The Britannia 300LR is powered by four Proteus 755 engines and is capable of carrying 90 passengers non-stop from London to New York. The Britannia mark 250LR is the mark 300LR with a large cargo door forward of the wing and a strengthened floor in the front fuselage for heavy freight.

Air Liners. Australian National Airways have ordered a fleet of Herald air liners from HANDLEY PAGE LTD., Cricklewood, London, N.W.2, for service on their Australian-wide network of routes. The Herald aircraft carries passengers or freight, or a combination of both, and can operate from primitive airfields under a wide range of climatic conditions. It is a four-engined, pressurised high-wing monoplane of 34,000 lb. all-up weight. It can carry up to a maximum of 44 passengers or more than 4¼ tons of freight, or combinations of both, at cruising speeds of 200 m.p.h.

Road Vehicles. During the first six weeks of 1955, TRANSPORT VEHICLES (DAIMLER) LTD., COVENTRY, have received orders for passenger-vehicle chassis and complete vehicles valued at £500,000. An order for 70 complete single-deck vehicles has been received from the Auckland Transport Board, New Zealand. In addition, numerous municipalities in the United Kingdom, including Dundee, Leeds, Swindon, Coventry, and Stalybridge have placed orders for a total of 75 double-deck chassis.



Opencast coal mining is a task for the civil-engineering contractor making use of the largest available earth-moving equipment and working both day and, as shown here, night shifts under floodlights.

WINNING OPENCAST COAL

5 MILLION TON CONTRACT IN NORTHUMBERLAND

There are a number of interesting features about the new opencast coal contract awarded to Richard Costain Limited, London, by the National Coal Board. It is the largest single contract for working opencast coal ever to be placed in Great Britain and is 1 million tons larger than the Tirpentwys contract awarded 4 months ago. The site, at Acorn Bank Farm on the banks of the River Blyth in Northumberland, has 5 million tons of coal which are to be worked at the rate of about 750,000 tons a year.

The site is to be returned to agricultural use as quickly as possible and, to facilitate this, two road tunnels will be laid to the bottom of the "cut" to allow the coal to be transported to the surface while the site is being worked. Work will begin from the deepest end first and the tunnels will be covered over as the work advances. In this way it is hoped that the site will be restored to farming use progressively from the beginning of mining operations. This is the first time tunnels have been employed to restore land before all the coal has been taken out.

The site covers 440 acres, of which 300 acres will be mined. There are three seams of coal, 39 in., 31 in. and 84 in. thick respectively, and the depth of excavation will vary from 40 to 225 feet. The overburden, boulder clay, sandstone and shale are to be handled by two electric 1150-B Bucyrus walking drag-line excavators. Three electrically operated rock shovels will be used as well as the latest type of American pneumatic drills. The coal is to be extracted mainly for seaborne and export markets, and is to be transported to the Bebside disposal point near Blyth where it will be crushed, screened and sized.

A contract such as this draws attention to the problems of opencast working at their most sensitive point. A satisfactory flow of opencast coal depends on the successful collaboration of three parties: the National Coal Board, the civil-engineering contractor to whom the site is let for the extraction of the coal, and the land interest. It was a complaint at one time that neither the contractors nor the specialised machinery needed for opencast work were being fully employed. The use of land for this purpose, has also been a controversial issue and the slowness in arriving at decisions on the use of land has been quoted before now by the Coal Board as an obstacle to working out a long term opencast mining policy. The Acorn Bank Farm contract might be the beginning of a solution to such difficulties if no more.

* * *

"FUEL EFFICIENCY PAYS"

The National Industrial Fuel Efficiency Service (N.I.F.E.S.) in conjunction with the Combustion Engineering Association, are holding a conference entitled "Fuel Efficiency Pays" on March 29, 1955, in the Richmond Hall at Earls Court, during the National Factory Equipment Exhibition. The object of the conference is to stimulate interest in the efficient use of fuel and power, and speakers and subjects will be as follow: morning session, "Reducing Steam Raising Costs," by Mr. John Rylands, followed by "Economics of Power Supply," by Mr. J. R. Wheating; afternoon session, "Steam Saving Pays," by Sir Oliver Lyle, followed by "N.I.F.E.S. Contribution to Fuel Efficiency," by Mr. Leslie W. Jenkins. Inquiries regarding the conference should be made to the Joint Conference Office, 6 Duke-street, St. James, London, S.W.1.

* * *

TROPICAL HYGIENE

A lay course in tropical hygiene, intended for mine and site managers whose work in the tropics makes them responsible for the health and welfare of others, will be held at the Ross Institute of Tropical Hygiene, Keppel-street, London, W.C.1, from Monday, July 11 to 15 next. There is no fee for the course. It is arranged so that morning sessions provide continuous instruction on malaria and its control, other tropical diseases and problems, including housing and sanitation and protection against the heat, being considered in the afternoons. Inquiries and applications should be made to the organising secretary at the above address.

ELECTROMAGNETICALLY ENRICHED ISOTOPES

Harwell Conference

Arrangements are being made to hold a conference on the production and utilisation of electromagnetically enriched isotopes at the Atomic Energy Research Establishment, Harwell, from Tuesday, September 13, to Friday, September 16, inclusive. Some of the leading members of the United States group of scientists responsible for the work on stable isotopes at Oak Ridge are attending, and provisional acceptances have also been received from the heads of groups engaged on work with electromagnetic separators in France, Holland and Denmark.

A detailed programme has not yet been prepared, but sessions will be held on the design and operation of large mass separators; ion sources and collector problems, especially those associated with high beam currents; the separation of radioactive materials; chemical aspects of work on isotope production; the preparation of isotopic targets; developments in the mass analysis of stable isotopes; and the utilisation of electromagnetically enriched isotopes.

The meeting will be largely occupied with problems relating to the electromagnetic separator itself, but papers will also be welcomed on applications of stable isotopes, especially on those of unusual types. In such contributions, the emphasis should be placed on the principles involved and not on the details of the large variety of techniques which users may employ. On the other hand, work on the application of isotopes of the lighter elements, such as those of hydrogen, carbon, nitrogen and oxygen, which are more economically enriched by other methods, is excluded from the scope of the conference.

Abstracts of papers must be submitted before April 30, and complete manuscripts not later than June 30, in order that advance copies of accepted contributions may be available before the conference. Accommodation can be arranged and, apart from the cost of that, the expenses of the conference will be limited to a small charge to cover food and transport. Persons desirous of attending the meeting are asked to communicate with Dr. M. L. Smith, Atomic Energy Research Establishment, Harwell, Didcot, Berkshire, as soon as possible. They are also asked to state whether they will be prepared to contribute a paper.

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MANAGING SMALL FIRMS

Harrogate Conference

The third Small Firms Conference to be organised by the British Institute of Management, with the support of the Federation of British Industries and the National Union of Manufacturers, will be held at Harrogate on Friday and Saturday, April 29 and 30.

Although the conference has been planned with the special problems of the smaller firm in mind, no particular limitations have been laid down as to the size or type of establishment to be represented. It is felt that the basic problems of management are very similar whatever the size of the undertaking, but that, in the smaller organisations, directors and senior managers have to be, to a considerable extent, their own specialists.

The Institute has accordingly planned the conference to cover all the main fields of management with the assistance of lecturers having a special interest in small undertakings. These speakers, from their own experience, will demonstrate how work study, incentive schemes, and the education and training of managers and supervisors can be as important to the small firm as to the large one.

After an informal dinner at 7 p.m., the conference will open on April 29 with a paper on "The Economic Outlook," by Mr. Roy Harrod. This will be followed by a reception at 10 p.m. Six sessions, in two simultaneous groups, will take place on the morning and afternoon of April 30. These meetings will deal with a new type of incentive; a production case study; the services of consultants; education and training in small firms; sales expansion; and the use of accountants. There will also be an informal discussion session. The conference will conclude with a dinner at which Mr. Osbert Peake, the Minister of Pensions and National Insurance, will be the speaker.

Further information regarding the conference, for which an attendance fee of £5 5*s.* is payable, may be obtained from the British Institute of Management, 8 Hill-street, London, W.1.

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BOURNEMOUTH HEALTH CONGRESS

The Royal Sanitary Institute has arranged to hold its 1955 congress, on problems associated with the maintenance of health, at Bournemouth, from Tuesday, April 26, to Friday, April 29, inclusive. Morning and afternoon sessions will be held each day, and there will be a variety of alternative visits to local docks, works and factories each afternoon.

At a meeting of the engineering and architecture section of the congress on April 27, there will be a symposium on "The Design and Lay-out of Crematoria," at which the opening address will be delivered by the President of the Institution of Civil Engineers, Mr. David M. Watson, B.Sc. (Eng.).

A meeting of the occupational health section will take place on the morning of April 28 and this session will open with a symposium on "Noise at Work." On the same morning, there will be a conference of engineers and surveyors attending the congress, at which there will be an address by the President of the Institution of Municipal Engineers, Mr. P. Parr, O.B.E., and papers on "Planning the Heat Services of a New Town," by Mr. W. A. Evetts, and on "The Problem of Refuse Disposal, with Special Reference to Tipping in Rural Areas," by Mr. H. E. Gilby, will be discussed.

The housing and town planning section will meet on the afternoon of April 29, when papers on "Planning for Industry," by Mr. T. F. Thomson, and on "A Study of Housing Maintenance Costs," by Mr. L. J. A. Stow, will be considered. Applications to attend the congress should be addressed to the secretary, Royal Sanitary Institute, 90 Buckingham Palace-road, London, S.W.1.

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LILLE INTERNATIONAL FAIR

This year will mark the 30th anniversary of the establishment of the international trade and commercial fair at Lille, in the centre of northern France. Buildings destroyed during the recent war have been completely reconstructed and the total floor space available for exhibitors now covers an area of about 200,000 square metres, nearly half of which is located in buildings of modern design. The principal separate building, known as the Grand Palace, covers an area of 10,000 square metres and is reserved for cycle and motor-car exhibits.

Seven other buildings of varying size are required to accommodate the remaining 25 sections into which the fair is divided. In addition to divisions catering for foodstuffs, wines, jewellery, leather goods, and footwear, there are sections devoted, respectively, to civil engineering, agricultural machinery, textile machinery, refrigerating equipment, sewing machines, office furniture, and plastics.

Between three and four thousand exhibitors, from some fifteen different countries, are expected to send materials and equipment for display at this year's fair. Further information may be obtained from the administration offices, Foire Internationale de Lille, Grand Palais, Lille (Nord), France.

FARADAY SOCIETY

Foundation of Bourke Lectures

A new lectureship, to be known as the Bourke lectureship, has been established by the Faraday Society, 6 Gray's Inn-square, London, W.C.1, with a view to enabling leading scientists from overseas to lecture at university centres in London, Oxford, Cambridge and the provinces. The purpose of the lectureship is the promotion of the study of physical chemistry and related subjects.

Dr. D. F. Hornig, Professor of Chemistry, Brown University, Rhode Island, United States, has been invited to deliver the first Bourke lectures. He will speak on "Bond Moments and Molecular Structure" at the Department of Chemistry, The University, Manchester, on Tuesday, March 15, commencing at 4 p.m.; and on "The Application of Shock Waves to Chemical Problems" at the Department of Physical Chemistry, The University, Cambridge, on Tuesday, May 3, commencing at 4.30 p.m.

These meetings are open to all interested persons without charge. Tickets will not be required.

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"POSITION OF RESPONSIBILITY"

I.C.E. Council's Requirements for Full Membership

In the March issue of the *Chartered Civil Engineer* the Council of the Institution of Civil Engineers draw the attention of associate members to the provisions required for transfer to the class of full member: that he shall be over 33 years of age and shall have had five years' employment in positions of responsibility in the design or execution of important engineering works. The note continues with a brief amplification of the Council's view of what constitutes a "position of responsibility" and cites a number of examples. They are: railway divisional engineers, senior engineering assistants in firms of consulting engineers of standing, resident engineers and contractors' agents and senior engineers on projects of some magnitude, superintending engineers in the Admiralty, municipal engineers of large towns, chief engineers in the Ministry of Transport, assistant directors of public works in the larger overseas territories, professors and senior members of the engineering staff of important universities and colleges. This list, it is made clear, is not complete and there are other positions of responsibility which are acceptable to the Council.

Noting that, at the present time, only one in six of all corporate members are full members, the note concludes, "It is possible that some associate members, although qualified to apply for transfer, are too modest to do so; such modesty is misplaced and cannot help to increase the prestige of the profession with the public or the prestige of the Institution. Experience has shown that, unless a professional man takes the opportunity to improve his status not only he but the profession as a whole will be the loser. The Council therefore ask most earnestly that the associate members who are qualified to do so should apply for transfer to full membership."

* * *

SETTING ADHESIVES BY ELECTRIC RESISTANCE HEATING

Instruction Course

A four-day course of instruction on electrical resistance heating for setting adhesives is being arranged by the Furniture Development Council. It is to be held in London at the end of June. Particulars can be obtained from the Council at 11 Adelphi Terrace, London, W.C.2.

SPECIFICATIONS OF SHEET METALS

NEED FOR CLOSER PRODUCER-USER LIAISON

The second day of the Winter Conference of the Sheet and Strip Metal Users' Technical Association, held in London on February 24 and 25, was devoted to a critical survey of specifications and tolerances of sheet metals, eight short papers from both supplier and user points of view being presented and discussed.

Mr. G. G. Hoare, of J. F. Ratcliff (Metals), Limited, author of the first paper, recalled the "old days" when, he said, materials were made without specifications and the only complaints were received from persons who were "bad toolmakers." As matters stood at present, British Standards must not be swamped by the very considerable growth of private specifications. They should be flexible enough to render unnecessary these private specifications which were either close enough to them to be superfluous or remote enough to be unworkable. There were, however, many anomalies in the present British Standard specifications which should be removed.

There was no such thing as perfect rolled strip. It was not possible to examine every foot of the miles of metal turned out every day, and inspectorates should not be allowed to condemn tons of material on a result limited to a small testpiece. He would like to see the much-despised Erichsen test come back into favour.

PERIODICAL REVIEW OF STANDARDS

Mr. E. H. Williamson, in the discussion, said that the British Standards Institution could not take up every Press reference to something alleged to be unsatisfactory, or every letter suggesting an alteration in tolerances, but they were now trying to review every Standard by the time it was five years old, and reasoned arguments for changes would receive full consideration. Another speaker, Mr. J. D. Hammah, contended that public specifications could not deal with the intricacies of every industry, and there must always be room for the private specification, intelligently drafted by the user with some knowledge of the producer's conditions.

Dr. H. H. Scholefield and Mr. J. E. Riley, of the Telegraph Construction and Maintenance Company, Limited, the authors of the second paper, said that in some instances, as for example width tolerances, the manufacturer could fairly readily meet the customer's requirements, but in most cases, and particularly with regard to thickness tolerances and straightness, it was necessary to evolve mutually-acceptable specifications, each side having an appreciation of the other's problems. Under laboratory conditions material could be produced to the closest tolerances, but it was rarely practicable or economic to translate these conditions into commercial production.

In the course of the discussion, Mr. G. Murray emphasised that suppliers must put on limits which they knew could always be met, but for specialised purposes in mass-production industries supplier and user must agree on closer tolerances.

In the third paper, by Dr. J. D. Jevons and Mr. T. G. Woodward, of Joseph Lucas Limited, the authors drew attention to the serious troubles caused by excessive dimensional tolerances in the sheet and strip metals used for the manufacture of small engineering components by modern production methods. Users of strip considered the edge-bowing now occurring to be most serious; it could wreck expensive press tools or at least delay production by continual jamming, and often rendered side-cropping unavoidable, thus entailing the purchase and discard of a substantial proportion of unwanted metal. The insistent demand for increased production in the motor-car industry required, in many instances, the adoption of multi-stage tools, but these could not be used unless the suppliers of strip met the demands of the tool designers for closer dimensional tolerances and less edge-bowing. The present tendency to roll only wide strip and shear this to narrow widths meant that thickness tolerances, instead of improving, would get substantially worse. Tolerances in the United States and Germany were closer than those obtainable in this country.

Mr. H. Mole, who spoke in the discussion, pointed out that considerable extra expense was involved in meeting the demands of users employing high-speed follow-on tools. Users seemed reluctant to acknowledge this, but if some assurance were given that the extra cost would be met, so that a more accurate plant could be put down and the necessary extra wages paid, it should be possible to produce the material required. Another speaker, Mr. J. A. A. Frazer, also contended that the problem was one of cost. Persons engaged in pressing had developed the practice of using follow-on tools and must be saving a very great deal of money. The suppliers must meet the new requirements but should be able to pass on the cost of doing so. Dr. Jevons replied that even when the manufacturers offered to pay more they could not get the tolerances they required, because the rolling mills were too busy to take the necessary steps. This would force manufacturers away from the use of the new techniques and so be unable to compete with German and American firms.

WHO DRAFTS SPECIFICATIONS?

The last paper at the morning session was by Mr. H. M. Bigford, of T.I. Aluminium Limited, and Mr. E. Elliott, of the Aluminium Development Association. The authors pointed out the undesirability of using aircraft standards when the material was not required for aircraft, and emphasised the need for the correct use of the British Standards general engineering specifications for aluminium and its alloys. For most purposes material to British Standards would be satisfactory, but where special properties were important there must be close and early collaboration between purchaser and supplier. When a user complained about material to a British Standard specification he should ask himself whether it was not his own fault, because the users took part in drafting the specifications. On most British Standards Institution technical committees, however, there seemed to be many more representatives of producers than of users.

Mr. E. H. Williamson, in the discussion, pointed out that while the producers were usually allied in trade associations there were very few organisations of users. Manufacturers often objected to smaller tolerances on the ground that designers would ask for them even when they were not required. Mr. Bigford, in reply, said that the aluminium industry had adopted the "target tolerance" method; they said "We shall try to meet your tolerances, but we shall want you to pay a little more." Another speaker, Mr. H. R. Brooker, said it would be a very bad day when everybody made close-tolerance strip, because the great bulk of the material produced by commercial methods met the great bulk of the demand. There were far too many amateur specification-writers who were not content with asking for the British Standard specification, plus certain extra requirements, but drew up a completely new specification and then took it round the industry to see who would consider making the material at the ordinary commercial price.

At the afternoon session the first paper was presented by Mr. A. J. K. Honeyman, of the Steel Company of Wales, Limited, who said that there were far too many specifications, British Standard and other kinds, for steel, and the Iron and Steel Industry Committee of the British Standards Institution had at last set up a sub-committee to co-ordinate them. The international committee which was dealing with the standardising of tests was making slow progress. For sheet material, specifications were not of much value; the manufacturer, on receipt of an order, referred to his card-index record which contained particulars of the material supplied, the process carried out, and the behaviour of the material at the client's plant. New orders were rated according to the firm's metallurgical-department's estimate of the severity of the press work to be carried out. Steel could not be made to exact requirements, and it was the responsibility of the metallurgical department to ensure that the best steel went to the most difficult tasks.

Mr. G. Murray, during the discussion, contended that one evil of specifications was that they restricted people who wanted to improve their product and gave no incentive for such improvement.

HARDNESS CRITERIA

Mr. A. G. Molinder said that in most cases the nominal analysis of a steel might be considerably adjusted without impairing its properties. There were exceptions, such as deep-drawing material where extreme softness was sought at a definite carbon content. It was most important to specify the mechanical properties and measure them correctly. Steelmaker and user should speak the same language when dealing with hardness, and it should be possible to translate the requirements of the user into the testing methods of the producer. Customers had a tendency to give two or more hardness specifications, using different scales, which did not correspond. Swedish cold-rolling mills had three tolerance groups: normal rolling, accurate rolling, and extra-accurate rolling, the first of these being a little better than British Standard 1449. Technical contact between steelmaker and user should exist to a much greater extent than at present and should start as soon as possible.

Mr. R. W. Stobbs, of the Plessey Company, Limited, suggested, in the next paper, that when a standard listed an entire class of alloys, a page or two might be devoted to their general engineering properties. There was a tendency to forget that the results obtained from a single application of a uni-axial load were of restricted significance when selecting materials for components subjected to combined or repeated stresses. A substantial increase in tensile strength need not be accompanied by a corresponding improvement in fatigue strength.

Mr. E. Elliott, in the discussion, pointed out that a specification was not something which gave information, but a yardstick which ensured that the user got what he wanted and also told the manufacturer what he had to provide. The information for which Mr. Stobbs asked was better given in the publications of manufacturers and development associations.

Mr. J. F. Kayser, of Gillette Industries Limited, summing up, said that those engaged on mass production must always have the same material. It could be done, and his firm could buy steel to very close tolerances and were prepared to pay for it, because it enabled them to produce a cheap final product. Nothing was sillier than to say that the price of, say, a motor-car must be increased by £50 because steel had gone up by 10*s.* a ton, when the car did not contain a ton of steel.

Emphasising the effect of large tolerances, he took the example of British Standard 1470 for aluminium, where for strip of a nominal thickness of 0·012 in. there was a tolerance of $\pm$ 0·001 in. and the tensile figure could vary from 7·5 to 9·5 tons per square inch. If one combined the low strength with the low gauge and the high strength with the high gauge, one obtained a ratio of 1/1·488, a difference of 50 per cent. With sheet steel, British Standard 1449, it was possible to obtain in the same way a ratio of 1/1·47. Surely it was possible to do better than that? As a user he had not the slightest interest in the composition of the metal; so long as it was uniform and could be processed and heat-treated in a standard manner to give the desired results he did not care what it contained.

Labour Notes

STEEL OUTLOOK

Firm support for the view of the British Iron and Steel Federation that the steel industry in Britain will be even more successful this year than in 1954, is given in an editorial note in the February issue of *Man and Metal*, the journal of the Iron and Steel Trades Confederation. All the signs indicate, the journal affirms, that this expression of confidence is more than justified.

After a comparatively quiet beginning in the early months of last year, when steel consumers, largely influenced by the business recession in the United States, were rather more cautious in their attitude than events proved necessary, the increase in demands has gained such an impetus that there is, once again, a shortage of certain types of finished steel, in spite of the achievement of production records.

Difficulties are being experienced in meeting orders for joists and other types of heavy sections, as well as for strip and wire rods, and bars and billets for re-rolling. Supplies of sheet and tin-plate are far from sufficient to meet a demand which is greater than ever before. In spite of an increase of 15 per cent. in the production of sheet last year, it was necessary to supplement supplies for home consumption by the importation of about 175,000 tons.

DEMANDS FOR TIN-PLATE

A parallel situation has now arisen, the journal points out, in the tin-plate industry, in which British consumers' requirements of tin-plate are of such a magnitude that they could only be satisfied by seriously reducing exports.

To make any such reduction, the journal feels, would be extremely unwise. It is, in fact, of the greatest importance that Britain's exports of tin-plate should not only be maintained but, if it be humanly possible, increased. To cut off supplies from overseas customers at the present time "would be the height of folly."

There is a rational explanation, therefore, for the apparently paradoxical situation now existing, whereby substantial quantities of tin-plate are both entering and leaving Welsh ports at the same time. It is unlikely that the gap between supply and demand for sheet steel will be closed before next year, or that for tin-plate before 1957.

These are exceptions, however, and, in the main, the steel industry is keeping abreast of the unprecedented demands made upon it. Further substantial additions to the capacity of Britain's iron- and steel-making plants, due to be completed during the present year, will enable the industry to make a still greater advance in production and this should ensure that, with few exceptions, the increasing needs of the steel-consuming industries are met.

STEEL ERECTORS' STRIKES CONTINUE

There is at present no sign of any easing of the deadlock which has arisen in connection with the strikes of steel erectors in various parts of the country.

The national executive committee of the Constructional Engineering Union, to which the men belong, decided at a meeting in London last Sunday that there should be no slackening of the union's efforts to secure higher rates of pay and that strike action should continue. A further meeting of the committee is due to be held to-day.

Members of the union, who are employed on the erection of steel building frames, are seeking parity in wage rates with those paid to craftsmen in the building industry, and, for the past 19 weeks, have been taking part in sporadic strikes in different areas because their demands have not been met. The dispute originated at eleven building sites in the City of London towards the end of October but has now spread to 24 sites and affects rather more than 500 men.

The union is stated to have between 13,000 and 14,000 members engaged on steel-erection work and about 8,000 of these men are employed by firms affiliated to the Engineering and Allied Employers' National Federation.

When the claim was submitted to the employers' Federation some months ago, it was rejected on the ground that steel erectors did not rank as craftsmen and that, in any case, their wage rates were covered by existing agreements in the engineering industry.

AN EMPLOYER'S WARNING

References to the dangerous consequences which may follow any further prolongation of the steel erectors' strikes are contained in the annual statement of Sir Ellis Hunter, F.C.A., the chairman and managing director of Dorman Long and Company, Limited, to the firm's shareholders.

He states that a number of important structural-engineering contracts are being seriously delayed by these strikes. Steel structures have many advantages over reinforced-concrete erections, but, he points out, these advantages may well be discounted by customers if there is uncertainty regarding the completion of contracts for the building of steel frames.

Men involved in these strikes at building sites would be wise to consider the fact that they are presenting to rival forms of construction an advantage which may seriously prejudice not only their own prospects of employment, but also the prospects of the larger numbers of workpeople employed in the fabricating shops.

Although the steel erectors seek to obtain rates comparable to those of craftsmen in the building industry, Sir Ellis states, the men have not served an apprenticeship. By their own choice, the wages of steel erectors are governed by rates payable in the engineering industry and not by those obtaining in the building trade.

BRITISH SEAMEN STRIKE IN U.S.

Strike action by some 300 members of the crew of the British liner Queen of Bermuda last Saturday, while the vessel was in New York, might well have a serious effect on the Furness Bermuda Line's service between Bermuda and New York.

It is understood that a subsidy is already granted to the service by the Government of Bermuda owing to the severe competition from local air services, which, by reason of their speed and relatively low fares, are able to take the pick of the passenger traffic to the island. Any further financial complications arising from higher costs or decreased bookings might endanger a continuance of the service, which, incidentally, is of considerable importance to the population of Bermuda, owing to their dependence on imported goods.

Difficulties which had existed during the previous fortnight, owing to a dispute over wage rates, came to a head last Friday, when the ship's master dismissed six stewards forming the men's complaints committee, on the ground that they had placed insulting notes in the cabins of senior officers and had adopted a threatening attitude to members of the crew who did not share their grievances.

Three members of the committee were subsequently cleared of blame and reinstated. A large proportion of the crew expressed their dissatisfaction with this decision and asked for the reinstatement of the other three men. As a protest against the non-compliance with their demands, the dissident members of the crew walked off the ship. Appeals to the men by the British Vice-Consul in charge of shipping to return to their duties were met with derision.

As a result, the liner had to disembark some 560 passengers, and to sail for Bermuda to discharge her cargo, with rather less than one-third of her crew on board.

APPLICATIONS FOR RE-ENGAGEMENT

Although many of the men left behind in New York promptly applied to the owners, Furness, Withy and Company, Limited, for re-engagement on the existing terms, and some of them were reported to have offered to pay the cost of their passages to Bermuda by air, it was announced that there was little possibility of a normal service being resumed before the vessel's next sailing from New York, due to take place to-morrow.

Most of the men concerned in the dispute are stewards and the company announced on Monday that it was willing to re-engage the great majority of them. Representations from the men's union, the National Union of Seamen, had been made, the company stated, that men who were willing to sign on again in fulfilment of their previous engagement should be re-employed. The company added that there was no disagreement with the union.

The men were originally signed on in England last December for one year's service at an average wage of £39 5*s.* 8d. a month, plus a bonus of £10 14*s.* a month. In addition to asking for increased pay for overtime, the men wanted their bonus to be doubled. The existing bonus, however, is stated to be above prevailing British rates.

UNDERGROUND RAILWAY EMPLOYEES' WAGE CLAIM

The wage claim of the National Union of Railwaymen and the Associated Society of Locomotive Engineers and Firemen against the London Transport Executive, which was referred to the London Transport Wages Board, for determination, has now been settled.

As a result of an award by the Wages Board, announced last Friday, and accepted by both sides, members of the conciliation grades employed on London Underground Railways will receive increases ranging from 9*s.* 6*d.* to £1 2*s.* 6*d.* a week. These increases will be ante-dated to January 2 last.

Negotiations between the Executive and the two unions failed mainly owing to a difference of opinion on the rates for motormen. The Executive considered that these men, who drive the electric trains on London Underground Railways, should be paid rather less than the rate received by the drivers of main-line trains, mainly on account of the differing nature of their work and responsibilities.

There was a difference of about 6*s.* a week in the views of the two sides as to the increase which should be awarded to the men. By its decision, the Wages Board has endorsed the trade-union point of view and this is regarded as being very largely a victory for the National Union of Railwaymen.

The Wages Board considered that no grounds existed for disturbing the relationship which had existed for 35 years between the rates payable to motormen on London Underground Railways and those paid to main-line drivers. It is estimated that, in all, about 12,000 Underground employees will benefit.

NOTICES OF MEETINGS

Aslib

LONDON
Discussion on "Recent Developments in Universal Decimal Classification," opened by G. A. Lloyd. Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Fri., Mar. 18, 6 p.m.

Association of Supervising Electrical Engineers

LONDON
Discussion on "Space Heating by Electricity." Central London Branch. St. Ermin's Hotel, Caxton-street, S.W.1. Mon., Mar. 14, 7 p.m.
Film Evening. South-West London Branch. 32 Worple-road, Wimbledon, S.W.18. Wed., Mar. 16, 8.15 p.m.
MANCHESTER
"Transducers and Their Application to Industry," by T. H. Halstead. Manchester Branch. Engineers' Club, Albert-square, Manchester. Wed., Mar. 16, 7 p.m.
NOTTINGHAM
Film Evening. Nottingham Branch. Offices of the East Midlands Electricity Board, Smithy-row, Nottingham. Wed., Mar. 16, 7.30 p.m.
PRESTON
"Simple Measurement of Radiant Energy and the Calibration of Light Sources," by H. W. Cumming. Preston Branch. 19 Friargate, Preston. Wed., Mar. 16, 7.15 p.m.
WATFORD
"Earthing," by T. C. Gilbert. Watford Branch. Clarendon Hotel, Station-road, Watford, Hertfordshire. Thurs., Mar. 17, 8 p.m.

British Institution of Radio Engineers

EDINBURGH
Short papers by Section members. Scottish Section. Department of Natural Philosophy, The University, Edinburgh. Thurs., Mar. 17, 7 p.m.

Chadwick Trust

LONDON
"Silicosis," by Professor E. J. King. 26 Portland-place, W.1. Tues., Mar. 15, 5.30 p.m.

Chemical Engineering Group

LONDON
"Correlations for Use in Transport of Aqueous Suspensions of Fine Solids Through Pipes," by K. E. Spells; "Pumping Practice for Slurries," by C. J. Stairmand; and "Hydraulic Conveying," by C. J. Richardson. Geological Society, Burlington House, Piccadilly, W.1. Tues., Mar. 15, 5.30 p.m.

Chemical Society

LONDON
"Some Problems in the Chemistry of the Hemicelluloses," by Professor E. L. Hirst. Thurs., Mar. 17, 7.30 p.m.
ABERDEEN
"Fluorescence of Solutions," by Dr. E. J. Bowen. Aberdeen Branch. Robert Gordon's Technical College, Aberdeen. Thurs., Mar. 17, 7.30 p.m.
BRISTOL
"Recent Advances in Photography," by Dr. H. Baines. Bristol Branch. Chemistry Department, The University, Bristol. Thurs., Mar. 17, 7 p.m.
DURHAM
"New Developments in Analytical Chemistry," by Dr. R. Belcher. Newcastle and Durham Branch. Science Laboratories, The University, Durham. Mon., Mar. 14, 5.15 p.m.
GLASGOW
"Shapes of Molecules," by Dr. J. W. Linnett. Glasgow Branch. The University, Glasgow. Fri., Mar. 18, 7.15 p.m.

Diesel Engine Users Association

LONDON
"Fundamentals of Free Piston Engines and Their Applications," by Clive O. B. Beale and Evelyn S. L. Beale. Caxton Hall, Westminster, S.W.1. Thurs., Mar. 17, 2.30 p.m.

Engineers' Guild

LONDON
"Alpine Railway Engineering," by Cecil J. Allen. Metropolitan Branch. Caxton Hall, Westminster, S.W.1. Thurs., Mar. 17, 6 p.m.

Illuminating Engineering Society

LIVERPOOL
Various short papers by members. Liverpool Centre. Liverpool Engineering Society, 9 The Temple, 24 Dale-street, Liverpool. Tues., Mar. 15, 6.30 p.m.
MIDDLESBROUGH
"Studies in Interior Lighting," by J. M. Waldram. Tees-Side Group. Cleveland Scientific and Technical Institute, Corporation-road, Middesbrough. Wed., Mar. 16, 6.30 p.m.

Incorporated Plant Engineers

BIRMINGHAM
"Soil Stabilisation," by Dr. E. McKenzie Taylor. Birmingham Branch. Imperial Hotel, Birmingham. Fri., Mar. 18, 7.30 p.m.
BRISTOL
Annual General Meeting and Film Evening. Western Branch. Grand Hotel, Bristol. Wed., Mar. 16, 7.15 p.m.
CARDIFF
Discussion on "Oil Firing." South Wales Branch. South Wales Institute of Engineers, Park-place, Cardiff. Tues., Mar. 15, 7.15 p.m.
LIVERPOOL
Annual General Meeting. Merseyside and North Wales Branch. Royal Institution, Colquitt-street, Liverpool. Mon., Mar. 14, 7.15 p.m.
MANCHESTER
Annual General Meeting. Manchester Branch. Engineers' Club, Albert-square, Manchester. Tues., Mar. 15, 7.15 p.m.
PETERBOROUGH
Annual General Meeting. Peterborough Branch. Campbell Hotel, Bridge-street, Peterborough. Thurs., Mar. 17, 7.30 p.m.
ROCHESTER
"Industrial Lighting," by J. F. Roper. Kent Branch. Bull Hotel, Rochester. Wed., Mar. 16, 7 p.m.

Institute of British Foundrymen

COVENTRY
"Foundry Work for Diesel-Engine Castings," with film, by H. Haynes. Coventry Section. Technical College, Coventry. Tues., Mar. 15, 7.30 p.m.
DUNDEE
Annual General Meeting. North-East Scottish Section. Technical College, Dundee. Wed., Mar. 16, 7.30 p.m.

Institute of Fuel

BIRMINGHAM
"Selection and Use of Fuels in a Modern Engineering Heat-Treatment Department," by H. Oxley. Midland Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Tues., Mar. 15, 6 p.m.
LOUGHBOROUGH
Discussion on "The Application of Gas Turbines to Industry." East Midland Section. Loughborough College, Loughborough. Fri., Mar. 18, 7.15 p.m.
NEWCASTLE-UPON-TYNE
"Wind and Solar Energy," by Professor P. A. Sheppard. North-Eastern Section. King's College, Newcastle-upon-Tyne. Mon., Mar. 14, 6.30 p.m.
SHEFFIELD
"Smoke and the Law," by A. Marsh. Yorkshire Section. Royal Victoria Station Hotel, Sheffield. Wed., Mar. 16, 2.30 p.m.

Institute of Metals

GLASGOW
Annual General Meeting. "Post-War Light-Alloy Production," by E. Kasz. Scottish Local Section. 39 Elmbank-crescent, Glasgow, C.2. Mon., Mar. 14, 6.30 p.m.

Institute of Road Transport Engineers

LONDON
Discussion on "Aspects of Vehicle Insurance and Accident Assessment." Royal Society of Arts, John Adam-street, Adelphi, W.C.2. Thurs., Mar. 17, 6.30 p.m.
LEEDS
"Developments in Piston and Piston-Ring Design," by J. Hepworth. Yorkshire Centre. Hotel Metropole, King-street, Leeds. Thurs., Mar. 17, 7.30 p.m.
LIVERPOOL
Discussion on "The Application of Planetary Gears in Axle Design." North-West Centre. Adelphi Hotel, Liverpool. Wed., Mar. 16, 7.30 p.m.

Institute of Welding

GLASGOW
"Basic Welding Metallurgy," by W. I. Pumphrey. West of Scotland Branch. 39 Elmbank-crescent, Glasgow, C.2. Wed., Mar. 16, 7 p.m.

Institution of Chemical Engineers

MANCHESTER
"Instrumentation of a Nuclear Power Plant," by P. V. Koller. North-Western Branch. College of Technology, Manchester. Wed., Mar. 16, 7 p.m.

Institution of Civil Engineers

LONDON
"Air Transportation," by Sir Miles Thomas. Joint Students' and Graduates' Meetings of Institutions of Civil, Mechanical and Electrical Engineers. Mon., Mar. 14, 6.30 p.m. (Alteration of date.)
"Geophysical Methods of Exploration and Their Application to Civil-Engineering Problems," by Jack Robertshaw and P. D. Brown. Tues., Mar. 15, 5,30 p.m.
LIVERPOOL
"Peace-Time Activity of the Corps of Royal Engineers," by Brigadier A. N. Anstruther. North-Western Association. 9 The Temple, 24 Dale-street, Liverpool. Wed., Mar. 16, 6 p.m.

Institution of Electrical Engineers

LONDON
"The Mechanism of Sub-Harmonic Generation in a Feedback System," by Dr. J. C. West and J. L. Douce; and "The Transient Behaviour of Remote-Position-Control Systems with a Hard Spring Non-Linear Characteristic," by Dr. J. C. West and P. N. Nikiforuk. Measurements Section. Tues., Mar. 15, 5.30 p.m.
"An Examination of High-Voltage Direct-Current Testing Applied to Large Stator Windings," by R. T. Rushall and J. S. Simons. Supply Section. Wed., Mar. 16, 5.30 p.m.
"The Standardisation of Retail Electricity Tariffs," by A. O. Johnson and N. F. Marsh. Utilization and Supply Sections. Thurs., Mar. 17, 5.30 p.m.
BRADFORD
"Colour Television," by Dr. G. N. Patchett. North Midland Centre. Technical College, Bradford. Tues., Mar. 15, 6.30 p.m.
DERBY
"Possibilities of a Cross-Channel Power Link Between the British and French Supply Systems," by D. P. Sayers, M. E. Laborde and F. J. Lane. East Midland Centre. Offices of the East Midlands Electricity Board, Derby. Tues., Mar. 15, 6.30 p.m.
FARNBOROUGH
"A Transatlantic Telephone Cable," by Dr. M. J. Kelley, Sir W. Gordon Radley, G. W. Gilman and R. J. Halsey. Southern Centre. R.A.E. Technical College, Farnborough. Wed., Mar. 16, 7.30 p.m.
NEWCASTLE-UPON-TYNE
"Automatic Circuit Reclosers," by G. F. Peirson, A. H. Pollard and N. Care. North-Eastern Centre. Neville Hall, Westgate-road, Newcastle-upon-Tyne. Mon., Mar. 14, 6.15 p.m.

Institution of Heating and Ventilating Engineers

LONDON
"Experiments on Floor Heating by Means of a Heat Pump," by J. A. Sumner. Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, S.W.1. Wed., Mar. 16, 6 p.m.
BIRMINGHAM
"A Historical Review of the Development of Heating and Ventilating," by N. S. Billington. Birmingham Branch. Imperial Hotel, Birmingham. Thurs., Mar. 17, 6.30 p.m.
LEEDS
"Boiler Feed-Water Treatment," by D. Billingham. Yorkshire Branch. Hotel Metropole, Leeds. Wed., Mar. 16, 6.30 p.m.

Institution of Mechanical Engineers

LONDON
Discussion on "The Performance of Pressure Chargers and Scavenge Pumps for Internal-Combustion Engines." Internal Combustion Engine Group. Tues., Mar. 15, 6.45 p.m.
Annual General Meeting. Open to Corporate and Non-Corporate Members only. Fri., Mar. 18, 5.30 p.m.
BIRMINGHAM
James Clayton Lecture on "Heavy-Duty Truck Development in the United States," by Robert Cass. Midland Branch. James Watt Memorial Institute, Great Charles-street, Birmingham. Thurs., Mar. 17, 6 p.m.
BRISTOL
James Clayton Lecture, as above. Western Branch. Grand Hotel, Bristol. Mon., Mar. 14, 7 p.m.
LEEDS
"Rocket Propulsion," by Professor A. D. Baxter. Yorkshire Branch. The University, Leeds. Thurs., Mar. 17, 6.30 p.m.
MANCHESTER
James Clayton Lecture, as above. North-Western A.D. Centre. Engineers' Club, Albert-square, Manchester. Fri., Mar. 18, 7.15 p.m.
NEWARK-ON-TRENT
"The Production of a Technical Journal," by B. W. Pendred. East Midlands Branch. County Technical College, Newark-on-Trent. Wed., Mar. 16, 7 p.m.
SOUTHAMPTON
"Problems Associated with the Manufacture of Large Turbo-Alternators," by J. Henderson and J. Taylor. Southern Branch. Polygon Hotel, Southampton. Wed., Mar. 16, 7.15 p.m.

Institution of Mining and Metallurgy

LONDON
"Geology of the Roan Antelope Orebody," by J. J. Brummer; and "Handling Ore and Waste at Irwin Shaft, Roan Antelope Copper Mine," by J. H. Sinclair. Geological Society, Burlington House, Piccadilly, W.1. Thurs., Mar. 17, 5 p.m.

Institution of Production Engineers

BIRMINGHAM
Annual General Meeting. Birmingham Section. James Watt Memorial Institute, Birmingham. Wed., Mar. 16, 7 p.m.
DERBY
Annual General Meeting and Film Evening. Derby Section. College of Art, Green-lane, Derby. Mon., Mar. 14, 7 p.m.
LIVERPOOL
"Electronics as an Aid to Production," by Dr. H. A. Thomas. Liverpool Section. Exchange Hotel, Liverpool. Wed., Mar. 16, 7.30 p.m.
SHEFFIELD
Annual General Meeting. "The Practical Application of Production Engineering Research," by Dr. D. F. Galloway. Sheffield Section. Grand Hotel, Sheffield. Mon., Mar. 14, 6.30 p.m.

Institution of the Rubber Industry

BIRMINGHAM
"Abraded Tyre Treads," by V. E. Gough, J. H. Hardman and R. J. McLaren. Midland Section. James Watt Memorial Institute, Great Charles-street, Birmingham. Mon., Mar. 14, 6.45 p.m.
CARDIFF
"Properties and Applications of Latex," by E. W. Madge. South Wales and Monmouthshire Section. College of Technology, Cardiff. Mon., Mar. 14, 7.30 p.m.

Junior Institution of Engineers

LONDON
"Flow of Fluids," by R. F. Twist. Fri., Mar. 18, 7 p.m.

Reinforced Concrete Association

LONDON
"The Gifford-Udall-C.C.L. System and Recent Developments in Prestressed Concrete," by E. W. H. Gifford. 11 Upper Belgrave-street, S.W.1. Wed., Mar. 16, 6 p.m.

Royal Aeronautical Society

LONDON
Louis Bleriot Lecture on "Making Aeroplanes Independent of Runways," by Georges Hereil. Institution of Mechanical Engineers, 1 Birdcage-walk, S.W.1. Thurs., Mar. 17, 6 p.m.

The Royal Society

LONDON
"Kinemattic Waves—(1) Flood Movement in Long Rivers, (2) A Theory of Traffic Flow in Crowded Streets," by M. J. and Lighthill and G. Whitham. Thurs., Mar. 17, 4.30 p.m.

Royal Society of Arts

LONDON
"Mechanical Properties of Metals—I," by Dr. Hugh Ford. Mon., Mar. 14, 6 p.m.

The address and telephone number of the headquarters of each institution are given below. Meetings in the headquarters town are held there unless otherwise stated. Particulars for this column should reach the Editor not later than Monday morning in the week preceding the date of the meeting.

Aslib, 4 Palace-gate, London, W.8. (WEStern 6321.)
Association of Supervising Electrical Engineers, 23 Bloomsbury-square, London, W.C.1. (LANgham 3927.)
British Institution of Radio Engineers, 9 Bedford-square, London, W.C.1. (MUSeum 1901.)
Chadwick Trustees, 204 Abbey House, Victoria-street, London, S.W.1. (ABBey 6872.)
Chemical Engineering Group, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Chemical Society, Burlington House, Piccadilly, London, W.1. (REGent 0675.)
Diesel Engine Users Association, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Engineers' Guild, 78 Buckingham-gate, London, S.W.1. (ABBey 7315.)
Illuminating Engineering Society, 32 Victoria-street, London, S.W.1. (ABBey 5215.)
Incorporated Plant Engineers, 48 Drury-lane, Solihull, Birmingham. (Solihull 3021.)
Institute of British Foundrymen, St. John Street Chambers, Deansgate, Manchester 3. (Blackfriars 6178.)
Institute of Fuel, 18 Devonshire-street, Portland-place, London, W.1. (LANgham 7124.)
Institute of Metals, 4 Grosvenor-gardens, London, S.W.1. (SLOane 6233.)
Institute of Road Transport Engineers, 69 Victoria-street, London, S.W.1. (ABBey 6248.)
Institute of Welding, 2 Buckingham Palace-gardens, London, S.W.1. (SLOane 9851.)
Institution of Chemical Engineers, 56 Victoria-street, London, S.W.1. (VICtoria 6161.)
Institution of Civil Engineers, Great George-street, London, S.W.1. (WHItehall 4577.)
Institution of Electrical Engineers, Savoy-place, Victoria-embankment, London, W.C.2. (TEMple Bar 7676.)
Institution of Heating and Ventilating Engineers, 49 Cadogan-square, London, S.W.1. (SLOane 3158.)
Institution of Mechanical Engineers, 1 Birdcage-walk, St. James's Park, London, S.W.1. (WHItehall 7476.)
Institution of Mining and Metallurgy, Salisbury House, Finsbury-circus, London, E.C.2. (MONarch 2096.)
Institution of Production Engineers, 10 Chesterfield-street, London, W.1. (GROsvenor 5254.)
Institution of the Rubber Industry, 12 Whitehall, London, S.W.1. (WHItehall 5012.)
Junior Institution of Engineers, Pepys House, 14 Rochester-row, London, S.W.1. (VICtoria 0786.)
Reinforced Concrete Association, 94-98 Petty France, London, S.W.1. (ABBey 4504.)
Royal Aeronautical Society, 4 Hamilton-place, London, W.1. (GROsvenor 3515.)
Royal Society, Burlington House, Piccadilly, London, W.1. (REGent 3335.)
Royal Society of Arts, John Adam-street, Adelphi, London, W.C.2. (TRAfalgar 2366.)